september 1958
the
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engineers

Proceedings of the IRE

in this issue

THERMOELECTRON ENGINE

SPUTNIK I's LAST DAYS

NOISE IN MASER AMPLIFIERS

SPHERICAL COIL AS AN INDUCTOR

BINARY RECEPTION THROUGH FADING

DIFFRACTION BY MOUNTAINS

AIRBORNE REFRACTION ANOMALIES

CATHODE TEST BY NOISE MEASUREMENTS

STANDARDS ON INFORMATION THEORY TER

TRANSACTIONS ABSTRACTS

ABSTRACTS AND REFERENCES

RUN 17B
al Efficiency, η (%)
15
5
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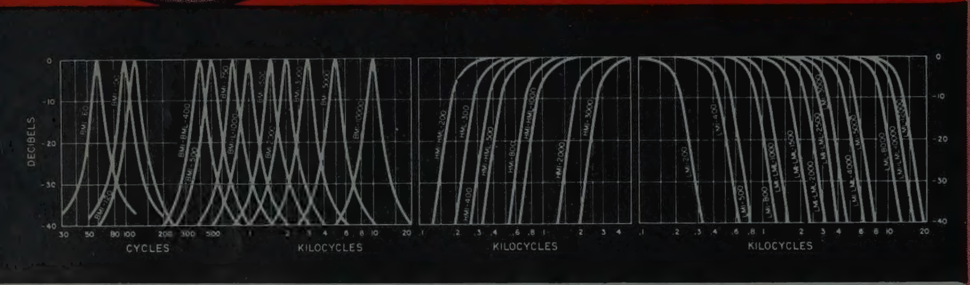
Thermoelectron Engine: Page 1574

FILTERS

FOR ALL APPLICATIONS FROM STOCK

HERMETICALLY SEALED TO MIL-T-27A & MIL-F-18327

UTC INTERSTAGE AND LINE FILTERS



STOCK TYPES
(number in figure is cycles)

- BMI-60
- BMI-100
- BMI-120
- BMI-400
- BMI-500
- BMI-750
- BMI-1000
- BMI-1500
- BMI-2000
- BMI-3000
- BMI-4000
- BMI-5000
- BMI-10000
- HMI-200
- HMI-400
- HMI-500
- HMI-800
- HMI-1000
- HMI-2000
- HMI-3000
- LMI-200
- LMI-400
- LMI-500
- LMI-800
- LMI-1000
- LMI-1500
- LMI-2000
- LMI-2500
- LMI-3000
- LMI-4000
- LMI-5000
- LMI-10000
- BML-400
- BML-1000
- HML-200
- HML-300
- HML-500
- HML-1000
- LML-1000
- LML-1500
- LML-2000
- LML-2500
- LML-4000
- LML-8000
- LML-10000
- LML-12000

This standardized group of filters covers most popular filter applications and frequencies. Units are in compact, drawn, magnetic shielding cases . . . 1³⁄₁₆ x 1¹¹⁄₁₆ base, 1⅝ high for BMI, LMI, BML; others 2½ high. There are six basic types:

BMI band pass units are 10K input, output to grid 2:1 gain. Attenuation is approximately 2 db at 3% from center frequency, then 40 db per octave.

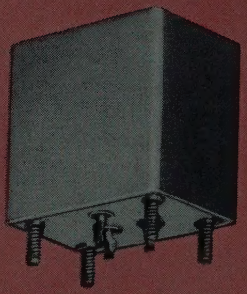
HMI high pass units are 10K in and out. Attenuation is less than 6 db at cut-off frequency and 35 db at .67 cut-off frequency.

LMI low pass units are 10K in and out. Attenuation is less than 6 db at cut-off frequency and 35 db at 1.5 cut-off frequency.

HML high pass filters are same as HMI but 500/600 ohms in and out.

LML low pass filters are same as LMI but 500/600 ohms in and out.

BML band pass units are same as BMI but 500/600 ohms input, output to grid, 9:1 gain.



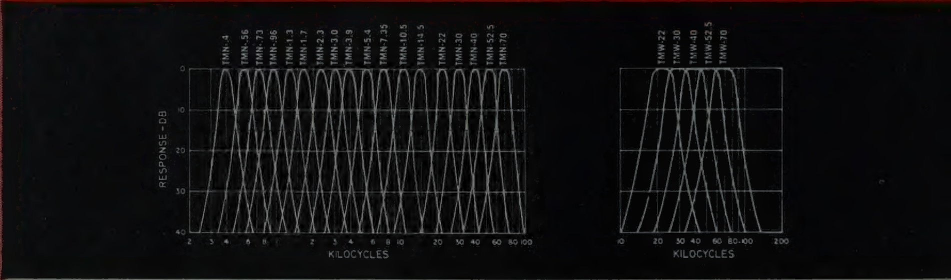
STOCK TYPES
(number in figure is KC)

- TMN-.4
- TMN-.56
- TMN-.73
- TMN-.96
- TMN-1.3
- TMN-1.7
- TMN-2.3
- TMN-3.0
- TMN-3.9
- TMN-5.4
- TMN-7.35
- TMN-10.5
- TMN-14.5
- TMN-22
- TMN-30
- TMN-40
- TMN-52.5
- TMN-70
- TMW-22
- TMW-30
- TMW-40
- TMW-52.5
- TMW-70

TMN-.4 thru TMN-1.7
¹¹⁄₁₆ x 1³⁄₃₂ x 2 inches
Weight ....3.5 oz.

TMN-2.3 thru TMW-70
²³⁄₃₂ x ²³⁄₃₂ x 1⅜ inches
Weight ....1.2 oz.

UTC TELEMETERING BAND PASS FILTERS

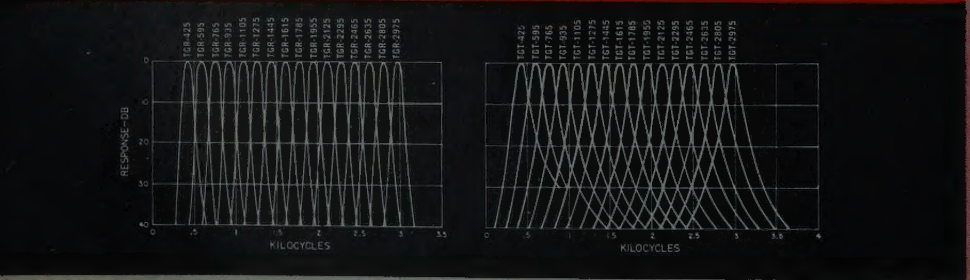


UTC standard telemetering filters provide extreme miniaturization with maximum stability, a complete set of 18 filters taking 19 cubic inches. They are 100K in and out and have an insertion loss of less than 6 db, 4 pin header for small Winchester socket.

TMN units are within 3 db at ± 7.5% of center frequency . . . down more than 18 db at ± 25% . . . more than 40 db beyond 1.75 and .58 center frequency.

TMW are within 3 db at ± 15% of center frequency . . . down more than 20 db at ± 50% . . . more than 40 db beyond 2.5 and .4 center frequency.

UTC TELEGRAPH TONE CHANNEL FILTERS



These band pass filters for multiplex transmitting and receiving provide maximum stability in miniature sizes. Both receiving and transmitting types are 600 ohms in and out, and employ 7 terminal header for sub-miniature 7 pin socket.

TGR receiving filters are within 3 db at ± 42.5 cycles from center frequency . . . down more than 30 db at ± 170 cycles . . . down more than 15 db at adjacent channel cross-over.

TGT transmitting filters are within 3 db at ± 42.5 cycles from center frequency . . . down more than 16 db at ± 170 cycles . . . down more than 7.5 db at adjacent channel cross-over.

STOCK TYPES
(number in figure is cycles)

RECEIVING

- TGR-425
- TGR-595
- TGR-765
- TGR-935
- TGR-1105
- TGR-1275
- TGR-1445
- TGR-1615
- TGR-1785
- TGR-1955
- TGR-2125
- TGR-2295
- TGR-2465
- TGR-2635
- TGR-2805
- TGR-2975

TRANSMITTING

- TGT-425
- TGT-595
- TGT-765
- TGT-935
- TGT-1105
- TGT-1275
- TGT-1445
- TGT-1615
- TGT-1785
- TGT-1955
- TGT-2125
- TGT-2295
- TGT-2465
- TGT-2635
- TGT-2805
- TGT-2975

TGT CASE
1½ x 1½ x 2½ in. 8 oz.

TGR CASE
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September, 1958

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Proceedings of the IRE©

contents

Poles and Zeros ... 1571

Donald B. Sinclair, Director, 1958 ... 1572

Scanning the Issue ... 1573

PAPERS

Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine, *G. N. Hatsopoulos and J. Kaye* ... 1574

Sputnik I's Last Days in Orbit, *J. D. Kraus and E. E. Dreese* ... 1580

Correction to "Thermoelectric Effects," *Frank E. Jaumot* ... 1587

Noise in Maser Amplifiers—Theory and Experiment, *J. P. Gordon and L. D. White* ... 1588

The Spherical Coil as an Inductor, Shield, or Antenna, *Harold A. Wheeler* ... 1595

Error Probabilities for Binary Symmetric Ideal Reception through Nonselective Slow Fading and Noise, *G. L. Turin* ... 1603

Diffraction by Smooth Cylindrical Mountains, *H. E. J. Neugebauer and M. P. Bachynski* ... 1619

Refraction Anomalies in Airborne Propagation, *Ming S. Wong* ... 1628

A Cathode Test Utilizing Noise Measurements, *W. Dahlke and F. Dlouhy* ... 1639

Correction to "IRE Standards on Radio Aids to Navigation: Definition of Terms, 1954" ... 1645

IRE Standards on Information Theory: Definitions of Terms, 1958 ... 1646

CORRESPONDENCE

Optimum Finite Code Groups, *J. E. Storer and R. Turyn* ... 1649

WWV Standard Frequency Transmissions, *W. D. George* ... 1649

Storage Capacity in Meteor-Burst Communication Systems, *Walter A. Helbig* ... 1649

Radio Engineering Use of the Cayley-Klein Model of Three-Dimensional Hyperbolic Space, *E. F. Bolinder* ... 1650

Properties of Root Loci, *C. S. Lorens* ... 1651

A Proposed Technique for the Improvement of Range Determination with Noise Radar, *Harry Hochstadt* ... 1652

Estimates of Entropy of a Message Source, *Carmen N. Campopiano* ... 1652

Minimum Weight Solenoid Systems, *G. M. Clarke* ... 1652

Various Definitions of the Delta Entities, *Otomar Pankraz* ... 1653

Some Comments on Minimum Triggering Signals, *J. L. Dautremont, Jr.* ... 1654

A Low-Noise Nonlinear Reactance Traveling-Wave Amplifier, *R. S. Engelbrecht* ... 1655

The Electron Optical Action of an Annular Aperture Lens, *L. A. Harris* ... 1655

Pulse Modulation Transmitted through a Linearly Modulated Transit-Time Device, *V. Met* ... 1656

Phase Dependence of a Ferromagnetic Microwave Amplifier, *W. L. Whirry and F. B. Wang* 1657

Analysis of Traveling-Wave Tubes with Tapered Velocity Parameter, *D. V. Geppert* ... 1658

REVIEWS

Scanning the TRANSACTIONS ... 1661

Books:

"Mass Spectroscopy," by H. E. Duckworth, *Reviewed by Harold C. Mattraw* ... 1662

"Introduction to Electromagnetic Engineering," by R. F. Harrington, *Reviewed by L. A. Manning* ... 1662

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

continued

"Transients in Electrical Circuits," by G. V. Lago and D. L. Waidelich, *Reviewed by G. B. Herzog* 1663
"Modern Computing Methods," *Reviewed by L. N. Ridenour* 1663
"Einführung in die Mikrowellen-Elektronik Tiel II: Lauffeldröhren," by Werner Kleen and Klaus Pöschl, *Reviewed by W. J. Albersheim* 1663
"Principles of Electricity," (3rd ed.) by Leigh Page and N. I. Adams, Jr., *Reviewed by E. T. Jaynes* 1664

ABSTRACTS

Abstracts of IRE Transactions 1665
Abstracts and References 1668

IRE NEWS AND NOTES

Calendar of Coming Events and Authors' Deadlines 14A
Call for Papers, 1959 IRE National Convention 14A
Obituary 20A
1958 IRE WESCON Convention Record 20A
IRE Canadian Convention 22A
Annual Conference on Industrial Electronics 26A
Annual Broadcast Symposium 26A
National Symposium on Engineering Writing and Speech 28A
National Symposium on Extended Range and Space Communications 28A
Professional Groups 30A
Sections and Subsections 30A, 34A

DEPARTMENTS

Contributors 1659
IRE People 42A
Industrial Engineering Notes 106A
Meetings with Exhibits 8A
Membership 62A
News—New Products 40A
Positions Open 134A
Positions Wanted by Armed Forces Veterans 138A
Professional Group Meetings 84A
Section Meetings 94A
Advertising Index 186A

COVER A novel diode-type of thermoelectronic device has been developed at M.I.T. for converting heat directly into electrical energy with an efficiency of better than 10 per cent, as described on page 1574.

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Airborne Instruments Laboratory Monograph on page 4A.

SHIFT REGISTERS

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for computers
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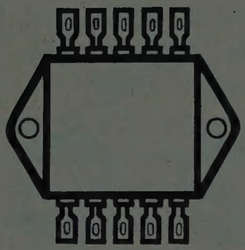

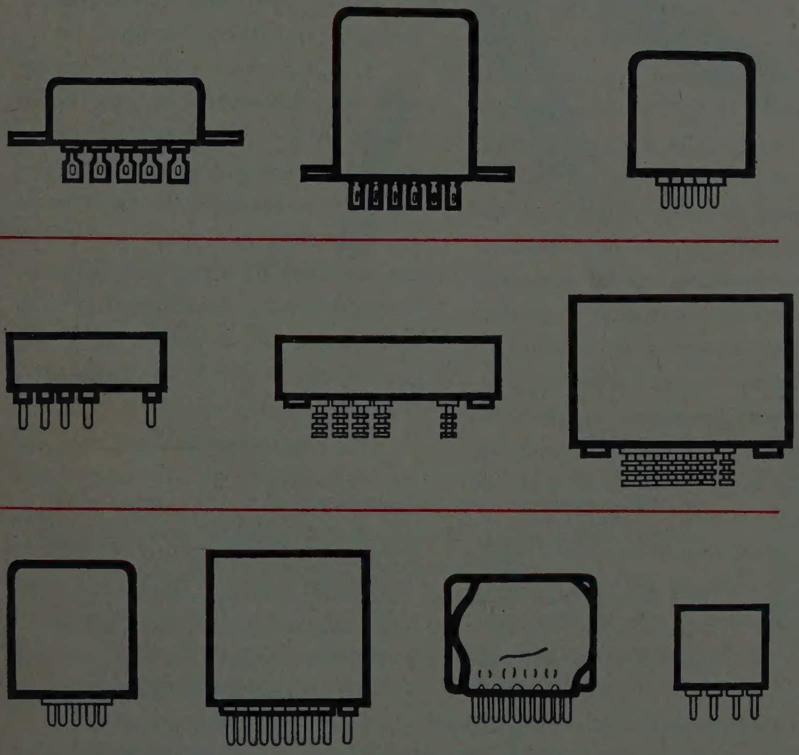

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Some of our friends may have been startled at the announcement that AIL has joined Cutler-Hammer. Recognizing that this move might not be understood by everyone, Art Loughren (Vice President of our Applied Research Division) wrote the following philosophical explanation. Although our audience probably has come to expect technical matter in this space (which we promise to supply in future advertisements), we ask your pardon for this month's comment on our recent move.

On Growing Up

"Growing up" has many meanings.

The original meaning, of course, refers to the increase of stature which an individual human being experiences in his progress toward maturity.

More often, we take "growing up" to refer to the increasing capacity to accept and to discharge responsibility which properly accompanies the increase in intellectual power, in physical power, and in ethical insight of soundly developed human beings.

Organizations of human beings can also grow up. The true measure of this growth, for organizations as well as for individual human beings, is the increasing capacity to accept and to discharge responsibility to society.

Growing up, as exhibited by increase in physical stature, terminates for the human being at roughly the age of twenty-one. But growing up, as measured by increase in capacity for responsibility, is bounded by no such arbitrary age limit or physical process. It continues as long as the individual is able and willing to do more on behalf of his fellow-men and himself.

Similarly, an organization of human beings continues to grow up as long as it is able and willing to increase its usefulness to the society of which it is a part. By this—the valid test, an organization may be youthful and growing at the age of one hundred and fifty years. (E. I. DuPont de Nemours comes to mind as an example.) And by this test, we can all recall organizations that exhibited senility when only five years old.

To grow is not the same thing as to grow up. Increase of bulk and increase of physical power are growth. But growing up requires that these be accompanied by increase in awareness that power must be wisely used.

An organization grows in capacity for responsibility by balanced growth in intellectual power, in physical power and in understanding of wise employment of power. Some of this growth occurs in the seasoning of the judgments of those who direct, some in the increase in both the acuity and the sheer amount of the intellectual resources available, and some in the increase in the purely physical aspects of the organization's control over nature.

The growing up of organizations proceeds usually at a gradual rate, with increases in wisdom of direction, increases in technical competence and increases in effectiveness of physical facilities coming along at a more or less matched pace. Occasionally, opportunity occurs to accelerate this process markedly. The joining of organizations whose attributes are largely complementary is perhaps the best example of this kind of opportunity.

Cutler-Hammer, Inc. and Airborne Instruments Laboratory started an examination of each other two years ago, to see whether or not such a complementary relationship existed. This examination revealed the desired complementary relation in large rather than trivial measure. It also revealed a close similarity of the two organizations in their codes of responsibility—to society, to employees and to shareholders.

The opportunity for marked acceleration of the growing up process has now been accepted. The former Airborne Instruments Laboratory, Inc. has now become the Airborne Instruments Laboratory Division of Cutler-Hammer, Inc.

Organizations which are by nature complementary do not begin effectively to complement each other merely by signing a merger agreement. New cooperative relationships must develop, and study and effort are required to bring this development promptly. Accelerated growth by merger of complementary organizations is partly by magic, but partly by hard work.

Having recognized and accepted our opportunity we are hard at the task of developing our new strength fully. We intend—and expect—to contribute to our fellow-men generally, to our fellow-employees and to our shareholders the fruits of this strength in adequate measure.

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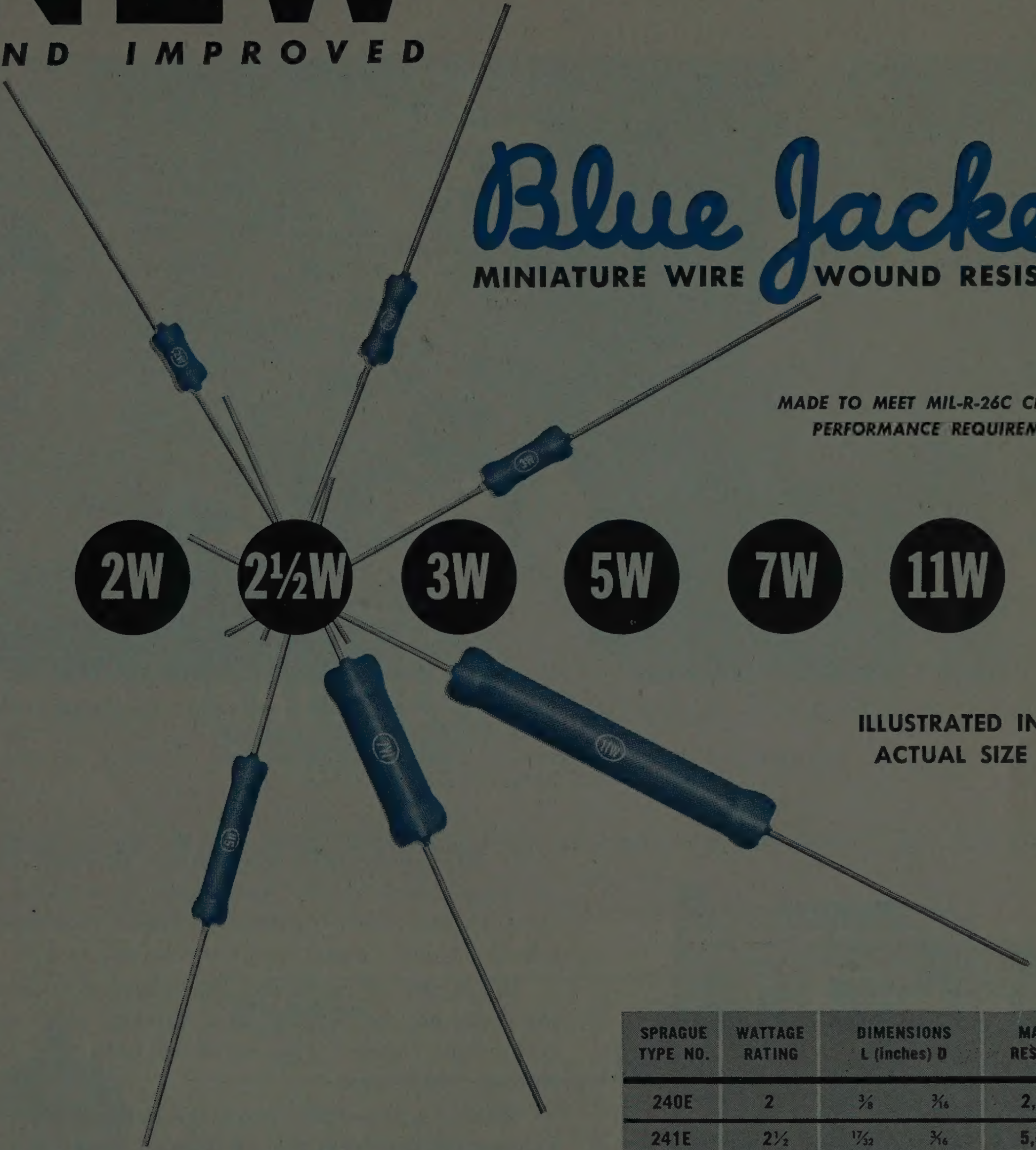

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241E	2½	17/32	3/16	5,000 Ω
242E	3	17/32	13/64	10,000 Ω
243E	5	15/16	13/64	30,000 Ω
244E	7	1 1/8	5/16	30,000 Ω
245E	11	1 7/8	5/16	50,000 Ω

Now a new improved construction gives even greater reliability and higher wattage ratings to Sprague's famous Blue Jacket miniature axial lead resistors.

Look at the small sizes shown in the illustrations above and you will recognize how ideal they are for use in miniature electronic equipment with either conventional wiring or printed wiring boards.

For the full technical story on these dependable miniaturized resistors, write for Engineering Bulletin 7410.

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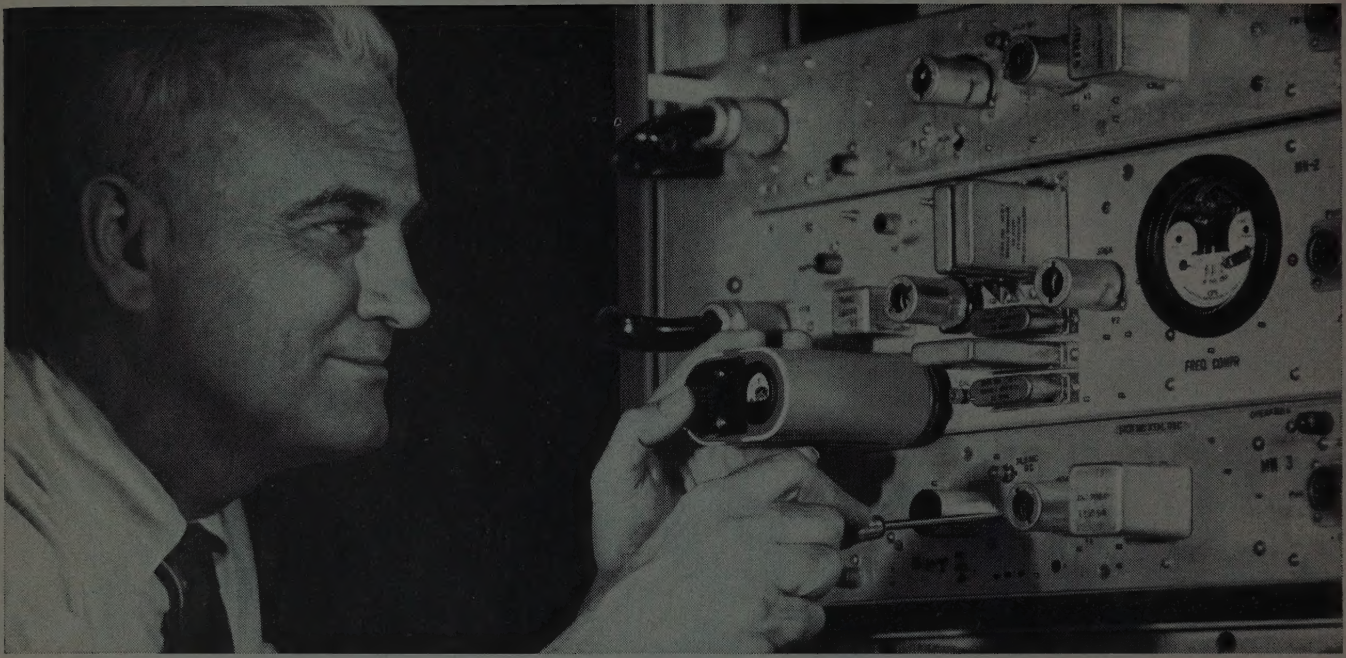
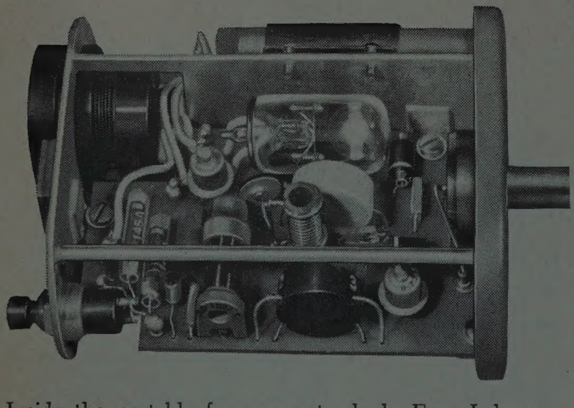
Bell Laboratories Announces Pocket-Sized Frequency Standard for Microwave Systems



Lawrence Koerner, who developed the portable frequency standard, demonstrates how the device can be plugged in at a radio relay station to supply a checking frequency. Battery-powered, the device maintains precision calibration for several months.



Inside the portable frequency standard. Four Laboratories-developed devices make it possible: (1) transistor, which converts the power from a battery to radio frequency oscillations; (2) voltage reference diode, which maintains constant voltage; (3) piezoelectric crystal unit of superlative stability; (4) thermistor, which corrects for temperature variations.

Microwave radio relay systems depend critically on the accuracy of their "carrier" frequencies. At scores of relay stations along a route, carrier frequency oscillators must be checked periodically against a signal from a precise standard.

In the past, the maintenance man has had to obtain his checking frequency by picking up a standard radio signal from a government station. This operation takes time—and requires elaborate equipment.

With a new *portable* frequency standard developed by Bell Laboratories engineers, the job is much simplified. To check an oscillator, the portable standard is plugged in, and a button is pressed. In seconds, it supplies a checking frequency accurate to one part in a million.

Until now, such precision in a frequency standard has been obtainable only in a laboratory. The new portable standard makes it available for routine use in the Bell System. First use of the standard will be to maintain frequency control in a new microwave system for telephone and TV, now under development at Bell Laboratories.

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High gain

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for military and industrial microwave relay I. F. service

CK5842 (417A) Triode*		**CK5847** (404A) Pentode
27000	G_m (μmhos)	13000
27.0	I_P (mA)	13.5
9.0	C_{in} (μμf)	7.2
1.8	C_{out} (μμf)	3.15
—	$C_{G\text{-}P}$ (μμf)	0.05 max.
0.55 max.	$C_{P\text{-}K}$ (μμf)	—

*Grounded Grid Service

Tubes shown actual size

* Raytheon Frame Grid construction assures: strength and rigidity
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FEATURES:

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- *Sealed Construction*
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- *Low Insertion Loss, High Attenuation*
- *Moderately Priced*

SLIM-TRAN Filters are connected to the D.C. input and eliminate hash and noise transmission to the external circuitry and also protect the switching transistors against line conducted transients. Stock units are available for center keying frequencies of 60, 400, 2000, and 5000 cycles. Other frequencies and current ratings are available on order. Special designs for commercial and military application can be supplied.

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HF40-2	400	2	0.4	30	1 x 1 x 2	4	8.00
HF40-5	400	5	0.2	36	1½ x 1¼ x 2	5	9.00
HF200-2	2,000	2	0.3	47	1 x 1 x 1½	3	8.50
HF200-5	2,000	5	0.2	50	1¼ x 1¼ x 2	5	9.50
HF500-1	5,000	1	0.4	54	1 x 1 x 1½	3	7.75

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Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.

Δ

September 12-13, 1958

Conference on Communications, Sheraton-Montrose Hotel, Cedar Rapids, Iowa

Exhibits: Mr. Don Loop, Box 948, Cedar Rapids, Iowa.

September 22-24, 1958

National Symposium on Telemetering, Americana Hotel, Miami Beach, Fla.

Exhibits: Mr. L. P. Clark, Tele-Dynamics, Inc., 5000 Parkside Ave., Philadelphia 31, Pa.

October 8-10, 1958

IRE Canadian Convention, Exhibition Park, Toronto, Canada.

Exhibits: Mr. F. G. Heath, IRE Canadian Convention, 1819 Yonge St., Toronto, Canada.

October 13-15, 1958

National Electronics Conference, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Brendon C. Hawkins, National Electronics Conference, Inc., 184 E. Randolph St., Chicago 1, Ill.

October 20-22, 1958

Fourth Annual Symposium on Aeronautical Communications, Hotel Utica, Utica, N.Y.

Exhibits: Mr. Robert E. Gaffney, 50 Cambridge Rd., Whitesboro, N.Y.

October 27-29, 1958

East Coast Aeronautical and Navigational Electronics Conference, Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.

Exhibits: Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

November 17-20, 1958

Conference on Magnetism & Magnetic Materials, Sheraton Hotel, Philadelphia, Pa.

Exhibits: Mr. D. O. Schwennesen, Magnetic Metals Co., Camden, N.J.

November 19-20, 1958

Northeast Electronics Research and Engineering Meeting (NEREM), Mechanics Building, Boston, Mass.

Exhibits: Mr. Stuart K. Gibson, Instruments of New England, 108 Greenwood Lane, Waltham 54, Mass.

December 3-5, 1958

Eastern Joint Computer Conference, Bellevue Stratford Hotel, Philadelphia, Pa.

Exhibits: Mr. John M. Broomall, Burroughs Corp., Paoli, Pa.

(Continued on page 10A)

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Mega-Node 240-A	5-220	0-16 at 50 ohms 0-23.8 at 300 ohms	unbal.—50, 75, 150, 300, ∞ bal.—100, 150, 300, 600, ∞	$325.00
Mega-Node 175-A	50-500	0-19	balanced—300	$325.00
Mega-Node 403-A	3-500	0-19	unbalanced—50	$325.00
Mega-Node-Sr. 250-B	10-3000	0-20	unbalanced—50	$790.00
Rada-Node 600-A	5-400	0-23.8 depending on impedance	unbalanced as specified	$1395.00
	10-3000	0-20	unbal. nom. 50	$1865.00
	1120-26,500	15.28 or 15.8	waveguide	†
Micro-Node 1080-A	3700-4200	0-15.8	waveguide	$725.00

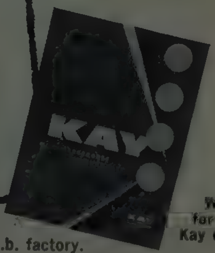
†With Microwave Mega-Nodes as Accessory — prices below

Microwave Mega-Nodes — argon and fluorescent gas discharge tubes. Noise output of 15.8 ±0.25 db for fluorescent tubes; 15.28 ±0.1 db for argon. Fluorescent tubes equipped with thermometer for correction factor of −0.05 db per degree above 32°C. No correction required for argon tubes. Supplied with power cables and fittings. Power Supply for any waveguide size: $95.00.

Waveguide Type AN	Flange AN	Frequency mc.	Catalog No. Argon	Catalog No. Fluor.	Price*
RG-69/U	UG-417/U	1120-1700	**	312-A	$595.00
RG-69/U	UG-417/U	1200-1400	311-A	310-A	$395.00
RG-104/U	UG-435/U	1700-2600	**	870-A	$495.00
RG-112/U	UG-553/U	2200-3300	**	880-A	$495.00
RG-48/U	UG-214/U	2600-3900	261-A	260-A	$175.00††
RG-49/U	UG-149/U	3900-5850	271-A	270-A	$175.00††
RG-50/U	UG-344/U	5850-8200	281-A	280-A	$175.00††
RG-51/U	UG-51/U	7050-10,000	291-A	290-A	$175.00††
RG-52/U	UG-39/U	8200-12,400	[illegible]01-A	300-A	$175.00††
RG-91/U	UG-419/U	12,400-18,000	521-A	**	$250.00
RG-53/U	UG-425/U	18,000-26,500	531-A	**	$250.00

†† Any three plus power supply: $595.00. Any in excess of three: $167.00 ea.
** None available.

*All prices f.o.b. factory.



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Meetings with Exhibits

(Continued from page 8A)

December 3-5, 1958

Second National Symposium on Global Communications, Colonial Inn Desert Ranch, St. Petersburg Beach, Fla.
Exhibits: Mr. Robert L. Lazarchik, Sperry-Rand Corp., P.O. Box 1828, Clearwater, Fla.

December 4-5, 1958

PGVC Annual Meeting, Hotel Sherman, Chicago, Ill.
Exhibits: Mr. Frederick L. Hilton, 4501 Augusta Blvd., Chicago, Ill.

December 9-11, 1958

Mid-America Electronics Convention, Municipal Auditorium, Kansas City, Mo.
Exhibits: Mr. Leo Schlesselman, Bendix Aviation Corp., Box 1159, Kansas City 41, Mo.

March 2-6, 1959

Western Joint Computer Conference, Fairmont Hotel, San Francisco, Calif.
Exhibits: Mr. H. K. Farrar, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco 5, Calif.

March 23-26, 1959

Radio Engineering Show and National IRE Convention, New York Coliseum and Waldorf-Astoria Hotel, New York, N.Y.
Exhibits: Mr. William C. Copp, Institute of Radio Engineers, 72 West 45th St., New York 36, N.Y.

April 5-10, 1959

Fifth Nuclear Congress, Cleveland, Ohio.
Exhibits: Dr. John C. Simons, Jr., National Research Corp., 70 Memorial Drive, Cambridge 42, Mass.

April 16-18, 1959

South Western IRE Regional Conference & Electronics Show, Dallas Memorial Auditorium & Baker Hotel, Dallas, Tex.
Exhibits: Mr. John McNeely, Southwestern Bell Telephone Co., 308 South Akard St., Dallas 1, Tex.

May 4-6, 1959

National Aeronautical and Navigational Electronics Conference, Dayton Biltmore Hotel, Dayton, Ohio.
Exhibits: Mr. John Kinnally, 203 Talbott Bldg., Dayton 2, Ohio.

May 6-8, 1959

Seventh Regional Conference and Trade Show, University of New Mexico, Albuquerque, N.M.
Exhibits: Mr. H. S. Westcott, Jr., Hoover Electronics Co., 1122 C. San Mateo, S.E., Albuquerque, N.M.

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Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

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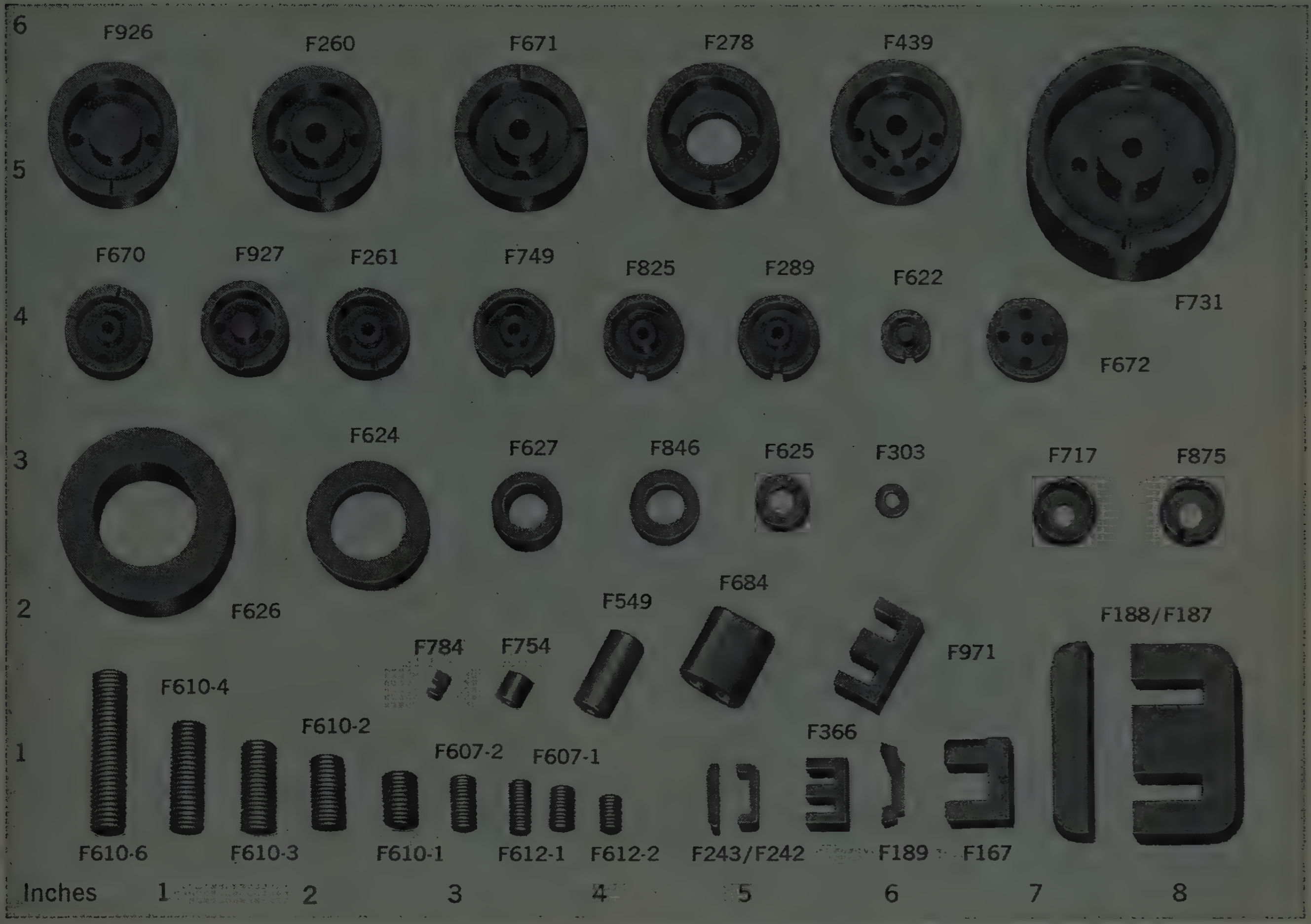
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Rush service for designers – use this handy materials selector chart

Ferrite Cores available in various materials for development and design engineers to cover specific frequency bands of operation from 1 KC to 50 megacycles. General Ceramics provides extra-fast service on sample quantities for development and will make prompt delivery on production parts in reasonable quantities. Call, wire or write General Ceramics Corporation, Keasbey, New Jersey. Please direct inquiries to Dept. P.

APPLICATION	DESIRED PROPERTIES	FREQUENCY	FERRAMIC BODY	SHAPES
Filter Inductors	High μQ, magnetic stability, sometimes adjustable	up to 200 kcs 200 kcs-10 mcs 10 mcs-80 mcs	"0-3","T-1" "Q-1" "Q-2"	Cup cores, toroids, C-cores, E-cores, slugs
IF Transformers	Moderate Q, high μ, magnetic stability, adjustable	465 mcs 40 mcs other	"Q-1" "Q-2" Materials for filter inductors apply	Cup cores, threaded cores, toroids
Antennae Cores	Moderate Q, high μ, magnetic stability	.5-10 mcs 10.50 mcs	"Q-1" "Q-2"	Rods, flat strips
Wide Band Transformers	High μ, moderately low loss	1 kc-400 kcs 1 kc-1 mc 200 kcs-30 mcs 10 mcs-100 mcs	"0-3", "T-1" "H" "Q-1" "Q-2"	Cup cores, toroids, C-cores, E-cores
Adjustable Inductors	High μ, moderately low loss	Same as Wide Band Transformers	Same as Wide Band Transformers	Rods, threaded cores, tunable cup cores
Tuners	High μ, moderate to high Q, magnetic stability, as much as 10 to 1 adjustability with mechanical or biasing methods	Up to 100 mcs	For high Q selective circuits, materials under filter inductors apply. For others, materials under wide band transformers apply	Threaded cores or rods for mechanical tuning. Toroids, C-cores, E-cores for biasing methods
Pulse Transformers	High μ, low loss, high saturation	Pulse	Materials under wide band transformers apply	Cup cores, toroids, C-cores, E-cores
Recording Heads	High μ, low loss, high saturation, resistance to wear	Audio, pulse	"H" "0-3", "T-1"	

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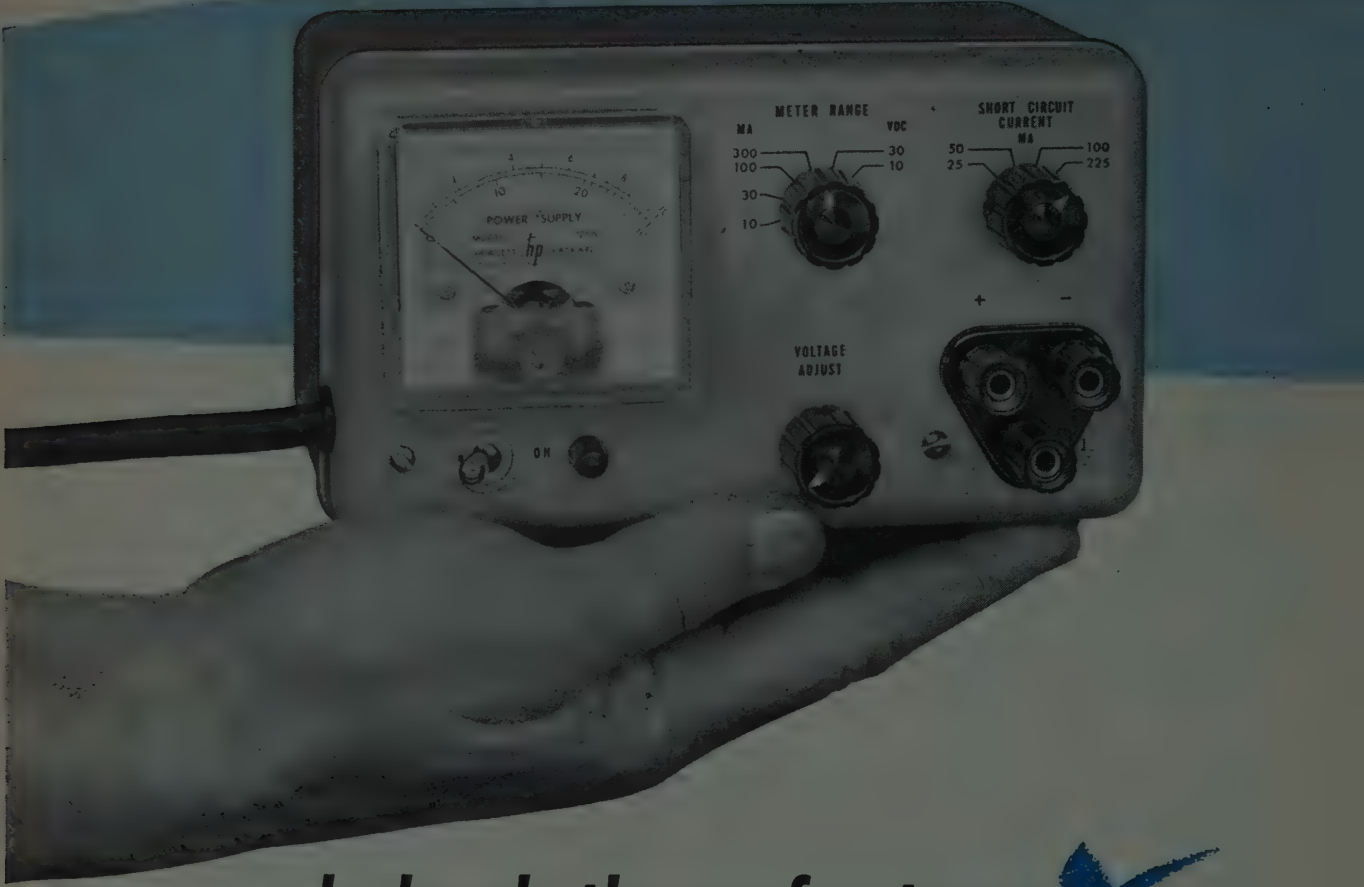


...and check these features

- ✓ **150 ma output 0 to 30 v dc, continuously variable**
- ✓ **High regulation; less than 0.3% or 30 mv change no-load to full-load**
- ✓ **Ripple less than 150 μv rms**
- ✓ **Metered output and current limiter prevent damage to transistors under test**
- ✓ **Compact transistorized construction**

New *-hp-* 721A Transistor Power Supply

Specifically designed to provide precision dc test voltages for transistor investigations, the new *-hp-* 721A Power Supply produces 0 to 30 volts at 150 milliamperes—sufficient for almost every type of transistor in use today.

Model 721A has a convenient 3-terminal output so that either positive or negative terminals may be grounded. Or, the supply may be "stacked" on another voltage for still greater usefulness. Need for additional metering and control equipment is eliminated since the 721A's front panel meter monitors either output voltage or current.

New hp 200 KC oscilloscope, $435.00.

TRANSISTOR POWER SUPPLY

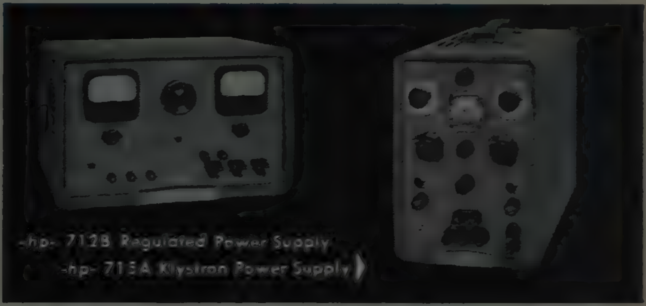
that prevents overload damage to transistors

An outstanding feature is a special circuit limiting output current to a nominal value (selected on the front panel in 4 steps—25, 50, 100 and 225 ma.) This unique feature prevents accidental overloads which otherwise cause costly damage to transistors under test.

Convenience of the new 721A is further increased by its compact size, low power consumption, simple controls and extreme dependability resulting from ultra-conservative circuit ratings. Model 721A, $145.

Other *-hp-* regulated and klystron power supplies

Simple operation, widest usefulness, high regulation, broad voltage range, rugged dependability—these characteristics have made *-hp-* Power Supplies basic experimental, testing and production tools in America's laboratories and factories. The many jobs these precision instruments perform daily include powering low level amplifiers, constant frequency oscillators, pulse circuits with heavy instantaneous current demands, oscillators, small transmitters, klystrons and "bread board" arrangements from the most simple to the most complex. Brief data on *-hp-* power supplies appear in the table at right. For complete details on *-hp-* supplies meeting your power needs, call your *-hp-* representative for demonstration on your bench. Or, write direct.


-hp- 712B Regulated Power Supply
-hp- 715A Klystron Power Supply ▶

Model	Characteristics	Regulation	Current	Voltage Range	Hum & Noise Level	Price
710B	General purpose dc/ac supply	±1%, 0 to 75 ma	100 ma	100 to 360 v dc; 6.3 v ac	Less than 0.0005 v	$110.00†
711A	Similar to 710B wider voltage range	Less than ±0.5% or 0.1 v, no load to full load	100 ma	0 to 500 v dc; 6.3 v ac	Ripple less than 0.1 mv	225.00†
712B	Heavy duty, 4 outputs, 0.1 μsec response	Less than 50 mv no load to full load	200 ma (pos. dc)	0 to 500 v dc; -300 v dc fixed bias; 0 to -150 v dc variable bias; 6.3 v ac	Ripple less than 500 μv	365.00†
715A	Klystron supply; square wave, external modulation	Less than 1%, no load to full load	50 ma (at 400 v)	250 to 400 v ac beam; 0 to 900 v dc reflector; 6.3 v ac	Ripple less than 7 mv	300.00

† Rack mount available at slight additional charge.

Data subject to change without notice. Prices f. o. b. factory.

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IRE News and Radio Notes

Calendar of Coming Events and Authors' Deadlines*

1958

Int'l Conf. for Analog Computations, Strasbourg, France, Sept. 1–7

Int'l Cybernetics Conv., Namur, Belgium, Sept. 3–10

Nat'l Conf. on Tube Tech., Western Union Audit., 60 Hudson St., New York, N.Y., Sept. 10-12

Biennial Communications Conf., Cedar Rapids, Iowa, Sept. 12–13

Int'l Nuclear Elec. Conf. UNESCO House, Paris, France, Sept. 16–20

Nat'l Symp. on Telemetering, Americana Hotel, Miami Beach, Fla., Sept. 22–24

Indus. Elec. Conf., Rackham Mem. Audit., Detroit, Mich., Sept. 24–25

Annual PGBTS Symp., Willard Hotel, Washington, D.C., Sept. 26–27

Silicon-Carbide Conf., Air Force Cambridge Research Center, Bedford, Mass., Sept.

Electrochemical Society, Chateau Laurier, Ottawa, Can., Sept. 28–Oct. 2

Audio Eng. Society, Conv., Hotel New Yorker, New York, N. Y. Sept. 29–Oct. 3

PGEWS Symp., New York City, Oct. 1–2

Radio Interference Reduction Conf., Armour Research Found., Chicago, Ill., Oct. 1–2

Symp. on Extend. Range and Space Commun., Lisner Audit., Geo. Wash. Univ., Washington, D.C., Oct. 6–7

IRE Canadian Convention, Exhibition Park, Toronto, Can., Oct. 8–10

Nat'l Electronics Conf., Hotel Sherman, Chicago, Ill., Oct. 13–15

1958 Int'l Systems Meeting, Penn-Sheraton Hotel, Pittsburgh, Pa., Oct. 13–15

PGCS Symp. on Aero. Communications, Hotel Utica, Utica, N. Y., Oct. 20–22

URSI Fall Meeting, Penn State Univ., Univ. Park, Pa., Oct. 21–22

Nat'l Simulation Conf., Dallas, Tex., Oct. 23–25

Nat'l Soc. of Prof. Engrs., St. Francis Hotel, San Francisco, Calif., Oct. 23–25

EIA-IRE Radio Fall Meeting, Sheraton Hotel, Rochester, N. Y., Oct. 27–29

East Coast Aero. & Nav. Elec. Conf., Lord Baltimore Hotel and 7th Regiment Armory, Baltimore, Md., Oct. 27–28

1958 Electron Devices Meeting, Shoreham Hotel, Washington, D. C., Oct. 30–Nov. 1

PGNS Mtg., Villa Motel, San Mateo, Calif., Nov. 6–7

Atlanta Section Conf., Atlanta-Biltmore Hotel, Atlanta, Ga., Nov. 17–19

Conf. on Magnetism and Mag. Materials, Sheraton Hotel, Philadelphia, Pa., Nov. 17–20

NEREM, Mechanics' Bldg., Boston, Mass., Nov. 19–20

Conf. on Elec. Tech. in Med. and Biol., Nicollet Hotel, Minneapolis, Minn., Nov. 19–21 (DL*: Oct. 1, R. Erskine,

(Continued on page 15A)

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* DL = Deadline for submitting abstracts.

Medical Group Studies New Applications of Computers

"Biology and Computers" will be the unifying theme of the Eleventh Annual Conference on Electrical Techniques in Medicine and Biology, to be held on November 19–21 at the Nicollet Hotel, Minneapolis, Minn. Cosponsors are the IRE, AIEE, and Instrument Society of America through their Joint Executive Committee on Medicine and Biology.

Two special sessions of the Conference will be devoted to applications of computers to biology. One will examine the possibilities of applying electronic computers to the theoretical and clinical problems of electrocardiography, and the related possibilities of machine analysis and partial electrocardiographic diagnosis of heart disease. The second will discuss computer ideas as applied to electroencephalography, or brain wave analysis. Several different means for analyzing data on the normal and abnormal processes of the brain, as learned through examination of the electric field within the brain and on the surface of the head, are already being planned and tested, and will be compared and discussed at this meeting.

A third special session will treat the inverse problem of developing computer applications on the basis of biological coding, transducer designs, and logic. It has been theorized that the performance of electronic computers could be improved, and their scope extended by utilizing knowledge of the computer-like systems that function in animals and plants. These developments would be important to instrumentation for space vehicles.

There will also be sessions of contributed papers in other areas of electronics as applied to biology and medicine. Abstracts of 250 words for these papers may be submitted until October 1 to Robert Erskine, Minneapolis Honeywell, 2753 Fourth Avenue South, Minneapolis, Minn. Forms for advance registration and hotel reservations may be obtained from the same address. The meeting is open to scientists, engineers, and physicians, and there will be a reduced registration fee for students.

URSI Meets at Penn State

The URSI Fall Meeting is scheduled for October 20–22, 1958 at Pennsylvania State University, University Park, Pa. The IRE Professional Groups on Information Theory and Antennas and Propagation are acting as cosponsors.

There will be a general technical session on October 21, to be followed by sessions with Commission 2 on tropospheric radio propagation, Commission 3 on ionospheric radio propagation, Commission 4 on radio noise of terrestrial origin, Commission 6 on radio waves and circuits, Subcommission 6.1 on information theory, Subcommission 6.2 on circuit theory, and Subcommission 6.3 on antennas and waveguides.

Call for Papers

1959 IRE National Convention

March 23–26, 1959

Waldorf-Astoria Hotel and New York Coliseum, New York, N. Y.

Prospective authors are requested to submit all of the following information by:

October 24, 1958

1. 100-word *abstract in triplicate*, title of paper, name and address
2. 500-word *summary in triplicate*, title of paper, name and address
3. An indication of the technical field in which the paper falls:

Aeronautical & Navigational Electronics
Antennas & Propagation
Audio
Automatic Control
Broadcast & Television Receivers
Broadcast Transmission Systems
Circuit Theory
Communications Systems
Component Parts
Education
Electron Devices
Electronic Computers
Engineering Management
Engineering Writing & Speech
Human Factors in Electronics
Industrial Electronics
Information Theory
Instrumentation
Medical Electronics
Microwave Theory & Techniques
Military Electronics
Nuclear Science
Production Techniques
Radio Frequency Interference
Reliability & Quality Control
Telemetry & Remote Control
Ultrasonics Engineering
Vehicular Communications

Note: Only considered are original papers not published or presented prior to the 1959 IRE National Convention; any necessary military or company clearance of paper must be granted prior to submittal.

Address all material to:
Dr. George L. Haller, Chairman
1959 Technical Program Committee
The Institute of Radio Engineers, Inc.
1 East 79 Street, New York 21, N. Y.

ARMY MARS RADIO NET WILL RESUME TECHNICAL BROADCASTS

The First Army Military Affiliate Radio System (MARS) Technical Net will resume operation with the first of its new series of technical symposia for amateur radio operators Wednesday evening at 9 to 10 P.M. (EDT) on 4030-kc single sideband (upper sideband) with the following programs: September 3—"Fifty Years of Reminiscence in Radio," E. J. Simon; September 10—"Features of Modern Amateur SSB Equipment," E. W. Pappenfus; September 17—"Applications of Increductor High Frequency Saturable Reactors," C. G. Sontheimer and H. F. Spirer; September 24—"Auditory Test Equipment for the Blind Radio Amateur and Technician," Robert Gunderson.

Selected speakers from the electronic and communication field will give talks followed by a question and answer session. Stations will call in from all parts of the first and second amateur call areas in the northeastern United States. Orderly radio-telephone procedure will be used.

Ed Piller, W2KPQ, of Whitestone, Long Island, technical director and net control station, said that based on past experience the talks should be heard within a radius of 1000 miles of New York on most of the evenings. John Novak, K2KUC, of Clifton, N. J., is the alternate net control station.

The net has made use of tapes to get outstanding speakers from various parts of the country. Live talks have already originated from five of the member stations.

ABSTRACTS DUE ON ELECTRONIC COMPONENTS AND MATERIALS

The 1959 Electronics Components Conference, sponsored by the IRE, AIEE, EIA, and WCEMA, is soliciting papers on electronic components and materials for presentation during its technical sessions, May 6–8, at the Benjamin Franklin Hotel, Philadelphia, Pa. Abstracts of 150–200 words should be submitted before October 1 to the Technical Program Chairman, Brig. Gen. E. R. Petzing, AGEP Secretariat, University of Pennsylvania, 200 S. 33rd St., Philadelphia 4, Pa.

The theme of the Conference, "New Concepts for the Space Age," has been subdivided into the following topics:

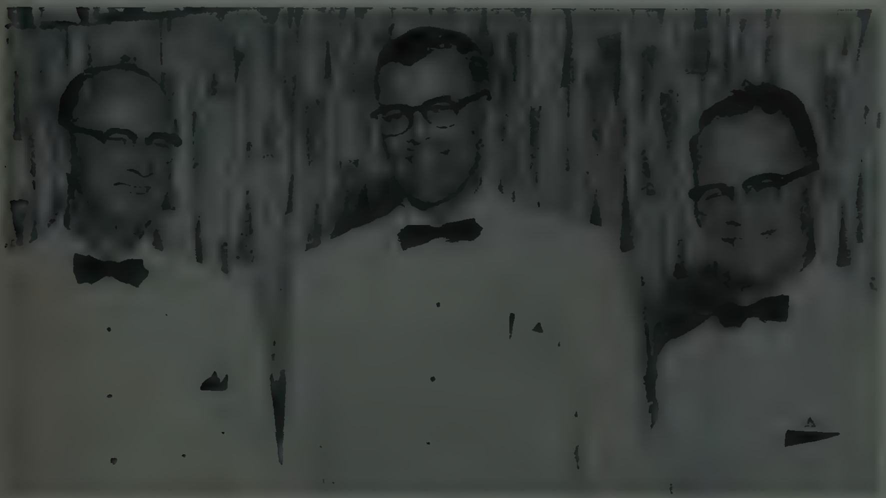
1) Components and Their Application in Space Vehicles
2) Microminiaturization and the New Component—The Micromodule
3) Developments in Materials and Their Application to Components
4) Professional and Tutorial Papers on the Mechanism of Failure (Operation) of Components
5) New Techniques for Electronic Filtering, Tuning, and Switching
6) Transistors, Diodes, and Rectifiers
7) Electron Tube Devices
8) Instrumentation and Control Devices
9) Survey of Improvements in Components
10) New Developments in Passive Components
11) Components for Military, Industrial, and Home Appliances—Applications of the Future
12) Radiation Effects.

SOLID-STATE CIRCUITS CONFERENCE SETS DEADLINE

The 1959 Solid-State Circuits Conference, sponsored by the IRE Professional Group on Circuit Theory, AIEE Committee on Electronics, IRE and AIEE Philadelphia Sections, and the University of Pennsylvania will be held on February 12 and 13, 1959, in Philadelphia, Pa.

Papers representing original contributions to circuit properties, circuit philosophy and techniques, and novel applications of solid-state devices are solicited for presentation. All papers should be circuit and application oriented.

Abstracts of 200 or more words explaining clearly the nature and significance of the contribution and the novelty of theoretical and experimental results should be sent no later than October 16, 1958 to A. P. Stern, Program Committee Chairman, General Electric Company, Electronics Park, Building 3, Room 113, Syracuse, N. Y.



Newly-elected 1958-1959 officers of the IRE Florida West Coast Section are pictured here as follows: *left to right* Capt. E. N. Dingley, Jr., secretary-treasurer; G. E. Reynolds, Jr., chairman; and Raymond Murphy, vice-chairman.

Calendar of Coming Events and Authors' Deadlines*

(*Continued from page 14A*)

Minneapolis Honeywell, 2753 Fourth Ave., Minneapolis)
Acoustical Soc. of Amer., Chicago, Ill., Nov. 20–22
Elec. Computer Exhibition, Olympia, London, Eng., Nov. 28–Dec. 4
EIA Conf. on Reliable Elec. Connections, Statler Hilton Hotel, Dallas, Texas, Dec. 2–4
Eastern Joint Computer Conf., Bellevue-Stratford Hotel, Philadelphia, Pa., Dec. 3–5 (DL*: Sept. 15, F. M. Verzuh, M.I.T. Comp. Ctr., Cambridge 39, Mass.
Nat'l Symp. on Global Comm., Colonial Inn, Desert Ranch, St. Petersburg, Fla., Dec. 3–5
PGVC Annual Mtg., Hotel Sherman, Chicago, Ill., Dec. 4–5
Mid-Amer. Elec. Convention, Mun. Audit., Kansas City, Mo., Dec. 9–11

1959

Rel. & Qual. Control Nat'l Symp., Bellevue-Stratford Hotel, Philadelphia, Pa., Jan. 12–13
Natl. RQC Symp., Bellevue-Stratford Hotel, Philadelphia, Pa., Jan. 12–14
Seventh Region Conf., Univ. of New Mex., Albuquerque, N. M., Feb. 2–4
Solid-State Circuits Conf., Univ. of Pa., Philadelphia, Pa., Feb. 12–13 (DL*: Oct. 16, A. P. Stern, G. E. Co., Elec. Park, Bldg. 3, Syracuse, N. Y.)
Western Joint Computer Conf., Fairmont Hotel, San Francisco, Calif., Mar. 3–5 (DL*: Oct. 1, M. L. Lesser, IBM Research Lab., San Jose, Calif.)
IRE Nat'l Convention, Coliseum and Waldorf-Astoria, New York City, Mar. 23–26
Silicon-Carbide Conf., Boston, Mass., Apr. 2–3 (DL*: Mar. 1, J. R. O'Connor, Elec. Matl. Sci. Lab., AF Cambridge Res. Ctr., Bedford, Mass.)
Nuclear Cong., Cleveland, Ohio, Apr. 5–10
SWIRECO, Dallas, Tex., Apr. 16–18 (DL*: Nov. 1, Frank Seay, Texas Instr. Inc., 6000 Lemmon Ave., Dallas 9, Tex.)
New Tech. in Elec. Indus. Instr., Philadelphia, Pa., Apr. 20–21
Nat'l Aero. Elec. Conf., Dayton, Ohio, May 4–6
URSI Spring Meeting, Washington, D. C., May 5–7
Elec. Components Conf., Ben Franklin Hotel, Philadelphia, Pa., May 6–8 (DL*: Oct. 1, Brig. Gen. E. R. Petzing, AGEP Secretariat, Univ. of Penn., 200 S. 33 St., Phila., Pa.)
7th Reg. Tech. Conf., Univ. of N. M., Albuquerque, N. M., May 6–8
Joint Conf. on Auto. Tech., Pick-Congress Hotel, Chicago, Ill., May 11–13
Prod. Tech. Symp., Villa Hotel, San Mateo, Calif., June 4–5
Int'l Conf. on Info. Processing, UNESCO House, Paris, France, June 15–20 (DL*: Oct. 1, A. S. Householder, Oak Ridge Nat'l Lab., Oak Ridge, Tenn.)
WESCON, San Francisco, Calif., Aug. 18–21

* DL = Deadline for submitting abstracts.

United States Participates in World Computer Conference

The First International Conference on Information Processing will be held June 15–20, 1959 in Paris, France, under the aegis of UNESCO. A United States Committee for the ICIP has been formed, and is jointly sponsored by the IRE, American Institute of Electrical Engineers, and Association for Computing Machinery. The chairman of this committee is I. L. Auerbach.

A tentative schedule of sixty-six papers to be presented in eleven three-hour sessions is being set up. Conference topics are expected to include methods of digital computing, logical design and common symbolic language for machines, automatic translation of languages, collection, storage, and retrieval of information, and pattern recognition and machine learning. There will also be symposia dealing with certain special problems. An exhibition of computing machines and apparatus, accompanied by pertinent demonstrations and discussions, and tours to convenient major European computer facilities will be arranged.

A United States program committee, under the direction of A. L. Householder, has been formed to secure 250-word abstracts of papers before October 1, 1958. After a preliminary international selection in October, all authors whose abstracts have been selected will be required to submit the full text of their papers for final international selection. Instructions concerning the presentation of the papers will be supplied at that time. Papers accepted for presentation at the conference will be preprinted in one language only, English or French, and copies will be supplied gratis to all conference participants who register early.

U. S. applications for attending the conference must be sent to S. Alexander, arrangements chairman of the U. S. Committee, who will forward them to UNESCO. The address of the U. S. Committee for the ICIP is: Box 4999, Washington 8, D. C.

Among the group of consultants in other countries participating in the conference are: U. Carteron of France, S. Comet of Sweden, A. Ghizzetti of Italy, C. Manneback of Belgium, D. Panov of Russia, R. de Possel of France, A. Walther of the Federal Republic of Germany, A. van Wijngaarden of the Netherlands, M. V. Wilkes of the United Kingdom, and H. Yamashita of Japan.

Five Broadcasts Scheduled on Air Force MARS Network

Air Force MARS, operating at 3295, 7540, and 15,715 kc, has announced the following schedule of programs for its Eastern Technical Network on Sunday afternoons, 2–4 P.M. EDT.

September 7—"Long-Range Radio Navigation Systems," Mortimer Rogoff, Executive Engineer, Federal Telecommunications Labs.

September 14—"Vacuum Tube Applications," Selig Gertzis, Chief Applications Engineer, Amperex Electronics Corp.

September 21—"Vacuum Tube Considerations," Bert Green, Engineer, Amperex Electronics Corp.

September 28—"Single-Sideband," William Kaufmann, Chief Engineer, Telechrome Corp.

October 5—"The Basics of Transistors," Charles Simmons, Engineer, Philco Corp.

NEC Promises Varied Program

A report on satellites and space stations and a discussion of automatic navigation will be featured at the 14th Annual National Electronics Conference, October 13–15 at the Hotel Sherman, Chicago, Ill.

In addition, there will be a panel discussion on "The Role of the Laboratory Program in Engineering Education" and a session with five journalists covering "Engineering Writing and Speech."

About one hundred scientific papers, given by men from sixteen states and three foreign countries, will include such topics as: antennas, audio, communications, computers, engineering management, industrial electronics, instrumentation, amplifiers, microwaves, radar and radio navigation, television, and transistors.

Commercial exhibits, highlighted by displays of electronic developments and devices, are scheduled. There will be social events and programs for wives of men attending.

Sponsors of NEC are: the IRE, American Institute of Electrical Engineers, Illinois Institute of Technology, and Illinois and Northwestern Universities. Participants are: Michigan, Michigan State, Notre Dame, Purdue, Wayne State, and Wisconsin universities, Electronic Industries Association, and the Society of Motion Picture and Television Engineers.

Dr. G. L. Haller (*right*), PGANE Chairman, accepted the PGANE Pioneer Award on behalf of Gen. A. F. Hegenberger from Gen. T. C. Rives (*left*) at the banquet of the National Aeronautical and Navigational Electronics Conference.

Space Technology Key Topic at PGMIL Convention

The theory and problems of outer-space engineering rated top priority with more than 3000 engineers and scientists who attended the Second National Convention on Military Electronics at the Sheraton Park Hotel in Washington, D. C. on June 16–18. Sessions on Space Technology and associated problems drew capacity crowds, and exhibit booths demonstrating Space Hardware had a record number of inquiring visitors. A special feature of the Convention was the Department of Defense scale models of the Army's Jupiter C missile and of the Explorer and Vanguard satellites.

Over 100 papers were presented at the technical sessions, which included five Confidential sessions. For the first time the published transactions of the Convention were issued at the time of registration. Confidential papers will not be published, but copies may be obtained from the authors after necessary clearance.

The latest military electronics equipment was on display in the Sheraton Park Exhibition Hall. Products ranged from subminiature printed circuits to a radio transmitting set weighing nearly a half ton.

W. M. Holaday, Director of Guided Missiles, Office of the Secretary of Defense addressed the annual Banquet, and Dr. S. W. Horwald, Manager, Air Arm Division, Westinghouse Corporation, Baltimore, Md., was speaker at the PGMIL Luncheon.

The U. S. Program Committee for the 1959 ICIP met recently at IRE Headquarters. They are (*left to right*): S. N. Alexander, NBS, Washington; Victor Yngve, M.I.T.; A. L. Samuel, IBM; A. S. Householder, *Chairman*, Oak Ridge National Laboratory; I. L. Auerbach, Auerbach Electronics; A. A. Cohen, Remington-Rand Univac; Gilbert King, IBM.

Radar and the Crusades

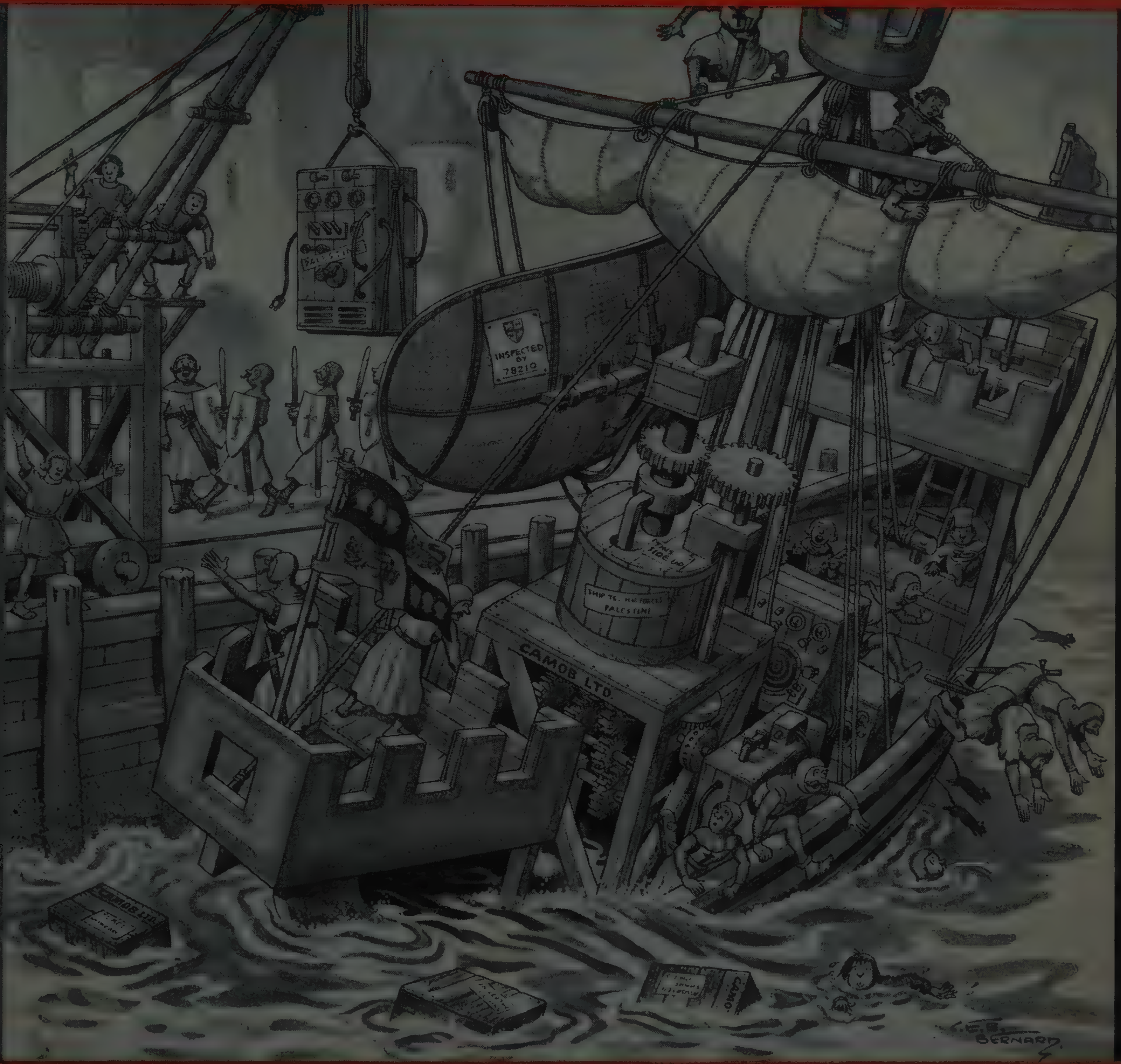
The scene: England at the time of the Third Crusade. The date: Tuesday, August 8, 1189. After years of secret preparation, the first radar installations intended for use in the Near East campaign were ready at last to begin their long sea journey. All England was agog with hope and excitement. The newspapers sent their best men to Stoke Poges-on-the-Chutney to cover the event.

The equipment was a towering monument to medieval genius — an achievement of the first water, so to speak. Mountains of stout English oak encased components marvelously wrought of myrrh, dried bat's wings, and the bones of sheep born on Thursday. The tubes were of stained glass, with fireflies inside to make them glow. Unfortunately, however, since this was long before the days of miniaturization, the installations were cumbersome as waltzing elephants and heavier then Dr. Jekyll's conscience. As a result, the ship went down faster than you can say "man overboard" — even before loading was completed.*

The nation's press reflected the disappointment felt throughout the land. Headlined the august London Times: "CRUSADER RADAR NO CRUISE AIDER." Commented Stoke Poges Confidential: "CONFIDENTIALLY, IT SINKS."

** as, for example, in modern miniaturized tubes like those made by a company which shall be nameless — called Bomac.*

No. 9 of a series . . . **BOMAC LOOKS AT RADAR THROUGH THE AGES**



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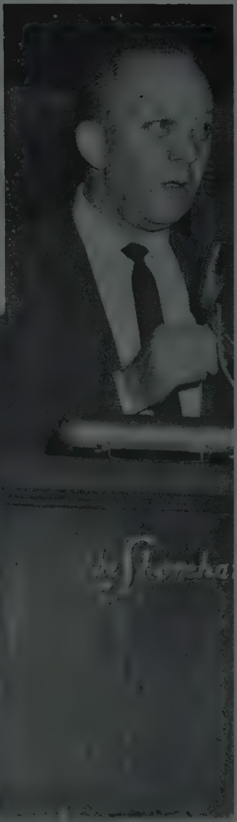
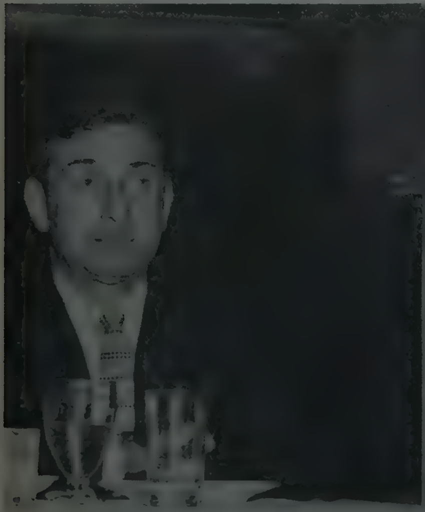
The IRE Board of Directors met during the National Aeronautical and Navigational Electronics Conference in Dayton, Ohio last May.

Conferences and Conventions

William M. Holaday, Director of Guided Missiles, Office of the Secretary of Defense addresses the annual Banquet during the PGMIL National Convention in Washington.



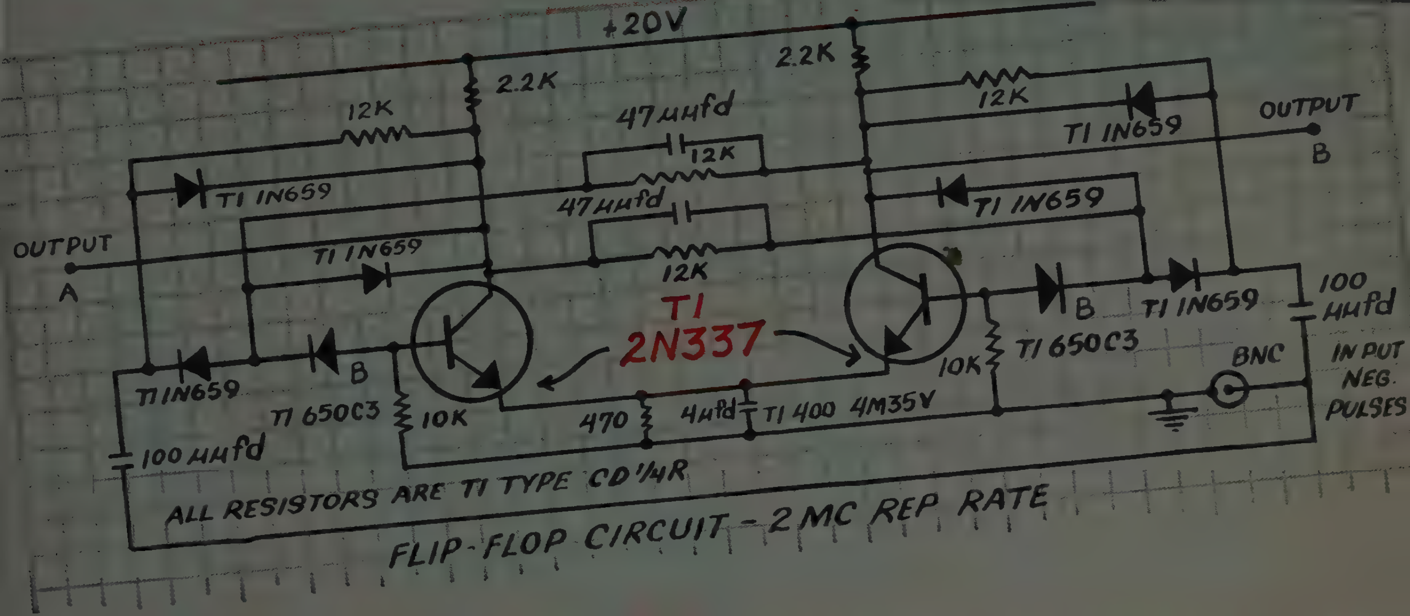


Capt. Chris Engelman (Ret.), toastmaster at the PGMIL Luncheon, introduces Dr. S. W. Horwald of Westinghouse Air Arm Division, who was featured speaker.

Making early plans for the 1959 Southwestern IRE Conference and Electronics Show, to be held April 16–18, 1959, at the Dallas Memorial Auditorium of Dallas, Tex., are Durward Tucker (*left*), conference chairman, and John McNeely (*right*), exhibits chairman.

Adm. Fritz Firth (U.S.N. Ret.) (*left*) a former member of the Administrative Committee discusses the Convention with Rear Adm. W. E. Cleaves (Ret.) 1957–1958 Chairman of PGMIL.

HIGH SPEED SWITCHING



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New improved TI 2N337 and 2N338 specifications provide greater design flexibility for your switching circuits . . . nuclear counters . . . pre-amplifiers . . . RF amplifiers . . . 455 KC IF amplifiers . . . and many other high frequency applications.

You get high gain at low current levels with TI diffused silicon transistors. High alpha cutoff . . . 10 mc min for 2N337, 20 mc min for 2N338 . . . and extremely low collector capacitance assure optimum performance in your switching and high frequency amplifier applications.

NEW IMPROVED SPECIFICATIONS FOR 2N337 AND 2N338

	from	to
BV_{CBO}	40 V max	45 V max
R_{CS}	300 Ω max	150 Ω max
h_{ib}	90 Ω max	80 Ω max

Consider TI's guaranteed specifications when you select semiconductor devices for your next transistor circuit.

design characteristics at 25° C ambient (except where advanced temperatures are indicated)

		test conditions		2N337			2N338			
				min	design center	max	min	design center	max	unit
I_{CBO}	Collector Cutoff Current	$V_{CB} = 20V$	$I_E = 0$	—	—	1	—	—	1	µA
	at 150°C	$V_{CB} = 20V$	$I_E = 0$	—	—	100	—	—	100	µA
BV_{CBO}	Breakdown Voltage	$I_{CB} = 50\mu A$	$I_E = 0$	45	—	—	45	—	—	V
BV_{EBO}	Breakdown Voltage	$I_{EB} = 50\mu A$	$I_C = 0$	1	—	—	1	—	—	V
h_{ib}	Input Impedance	$V_{CB} = 20V$	$I_E = -1mA$	30	50	80	30	50	80	Ohm
h_{ob}	Output Admittance	$V_{CB} = 20V$	$I_E = -1mA$	—	0.2	1	—	0.2	1	µmho
h_{rb}	Feedback Voltage Ratio	$V_{CB} = 20V$	$I_E = -1mA$	—	200	2000	—	300	2000	$X10^{-6}$
h_{fb}	Current Transfer Ratio	$V_{CB} = 20V$	$I_E = -1mA$	0.95	0.985	—	0.975	0.99	—	—
h_{FE}	DC Beta	$V_{CE} = 5V$	$I_C = 10mA$	20	35	55	45	80	150	—
$f_{\alpha b}$	Frequency Cutoff	$V_{CB} = 20V$	$I_E = -1mA$	10	20	—	20	30	—	mc
C_{ob}	Collector Capacitance*	$V_{CB} = 20V$	$I_E = -1mA$	—	1.2	3	—	1.2	3	µµf
R_{cs}	Saturation Resistance†	I_B ‡	$I_C = 10mA$	—	75	150	—	75	150	Ohm
h_{fe}	Current Transfer Ratio	$V_{CB} = 20V$	$I_E = -1mA, f = 2.5mc$	14	22	—	20	24	—	db
t_r	Rise time§			—	0.05	—	—	0.06	—	µsec
t_s	Storage Time			—	0.02	—	—	0.02	—	µsec
t_f	Fall time			—	0.08	—	—	0.14	—	µsec

* Measured at 1 mc † Common Emitter ‡ I_B = 1mA for 2N337, 0.5mA for 2N338 § Includes delay time (t_d)

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Meyer Leifer (*left*) retiring chairman of the San Francisco Section congratulates E. G. Goddard who succeeds him as chairman for 1958–1959. Other new officers are (*left to right*) V. B. Corey, vice-chairman, D. A. Dunn, secretary, and Stanley Kaisel, treasurer.

OBITUARY

Frank Cecil Exon (A'38–SM'47) died recently while he was returning to Australia from an assignment in Pakistan.

Appointed as Supervising Engineer under the Colombo Plan, Mr. Exon arrived in Pakistan in December, 1955 to supervise the installation and initial operation of the telecommunications equipment supplied by Australia for use by the Pakistan Department of Posts and Telegraphs.

His work took him to East and West Pakistan, where he assisted in setting up and implementing high-powered transmitters and receivers to augment internal and external telegraph and telephone communications, and trained a staff in their operation.

Mr. Exon was an Officer of the British Empire, and Vice-President of the Pakistan-Australia Association.

1958 IRE WESCON Convention Record

All available papers presented at the 1958 IRE WESCON Convention will appear in an IRE WESCON CONVENTION RECORD to be published in late Fall. The IRE WESCON CONVENTION RECORD will be issued in nine Parts, with each Part devoted to related subjects. Papers for all sessions except session 22 appeared on pages 18A–24A of the July issue.

Instructions on Ordering

1. If you are a member of a Professional Group above Student grade and have paid the group assessment by September 30, you will automatically receive, free of charge, that Part of the IRE WESCON CONVENTION RECORD pertaining to the field of interest of your group, as indicated in the chart below.

2. If you are not a member of an IRE Professional Group, IRE WESCON CONVENTION RECORD Parts may be purchased at the prices listed in the chart below. Orders must be accompanied by remittance, and to assure prompt delivery, should be sent immediately to The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y.

1958 IRE WESCON CONVENTION RECORD

Part	Subject	Free to Paid Members above Student Grade of the Following IRE Professional Groups	Prices for Members (M) Colleges & Libraries & Sub. Agencies (L) Non-Members (NM)		
			M	L	NM
1	Antennas & Propagation; Microwaves **Sessions: 5, 10, 20, 27, 30, 35, 40**	Antennas & Propagation Microwave Theory & Techniques	$ 5.50	$ 13.20	$ 16.50
2	Circuit Theory **Sessions: 9, 14, 17**	Circuit Theory	3.00	7.20	9.00
3	Electron Devices **Sessions: 11, 24, 28, 33, 38**	Electron Devices	3.75	9.00	11.25
4	Automatic Control; Computers; Human Factors; Information Theory **Sessions: 1, 4, 6, 18, 23, 29**	Automatic Control Electronic Computers Human Factors in Electronics Information Theory	8.00	19.20	24.00
5	Aeronautical; Instrumentation; Medical; Nuclear; Telemetry **Sessions: 3, 8, 13, 16, 19, 21, 39**	Aeronautical & Navigational Electronics Instrumentation Medical Electronics Nuclear Science Telemetry & Remote Control	8.50	20.40	25.50
6	Components; Industrial Electronics; Production; Reliability **Sessions: 2, 7, 26, 31, 34, 36**	Component Parts Industrial Electronics Production Techniques Reliability & Quality Control	4.50	10.80	13.50
7	Audio; Broadcast; Receivers **Sessions: 15, 32, 37**	Audio Broadcast & Television Receivers Broadcast Transmission Systems	3.25	7.80	9.75
8	Communications; Military; Vehicular **Sessions: 25, 42**	Communications Systems Military Electronics Vehicular Communications	2.50	6.00	7.50
9	Writing & Speech; Management	Engineering Writing & Speech Engineering Management	3.00	7.20	9.00
	Complete Set (9 Parts)		$42.00	$100.80	$126.00

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IRE Canadian Convention

OCTOBER 8–10, AUTOMOTIVE BUILDING, EXHIBITION PARK, TORONTO, CANADA

The Canadian Sections of the IRE will sponsor their third annual Convention and Exhibition in Toronto on October 8–10. Dr. George Sinclair, Chairman of the Executive Committee, has announced that 120 scientific and technical papers will be presented during the 25 sessions of the three-day Convention. Their subjects range from neurosonic surgery to the choice of a site for the Dominion Observatory's new radio telescope.

A total of more than 300 commercial exhibits will be assembled in Exhibition Park. Space has been reserved for scientific agencies in Britain, the United States, Russia, and France to display invited exhibits on Sputniks, Zeta, and other newsmaking developments.

For the first time, the complete text and illustrations of all technical papers presented will be reproduced in a Convention Record.

Engineering education will be the topic of the banquet address on October 9 by Col. Kurt Swinton, vice-president of the Encyclopaedia Britannica of Canada Ltd. An international panel of scientists will also discuss the balance between theory and practice in engineering education during the technical program.

In addition to the banquet, the Convention will feature an All-Industry Cocktail Party, and a program of varied activities for ladies.

Wednesday Afternoon, October 8

Electronics for Guided Missiles

"Selection Criteria for Missile Telemetry Systems," *P. Jackson, Canadair Ltd., Montreal.*

"A Hot Gas Bi-Stable Servo System for Guided Missiles," *D. Clendenning, Canadair Ltd., Montreal.*

"Magnetic Tape Recording," *A. VanLeeuwen, Canadair Ltd., Montreal.*

"Missile Controls Design Utilizing Automatic Digital and Analogue Computing Facilities," *W. A. Rawlins, Canadair Ltd., Montreal.*

"Batteries for High Altitude Applications," *H. Henshall, Canadian Armament Res. and Dev. Establishment, Valcartier, Quebec.*

Industrial Electronics I

"Choice of a Universal Logic Element," *N. L. Carlson, Canadian General Electric Co. Ltd., Peterborough.*

"Organization of Logic for the Universal Logic Element," *E. Boote, Canadian General Electric Co. Ltd., Peterborough.*

"Packaging Transistorized Static Control Devices," *K. Sheeran, Canadian General Electric Co. Ltd., Peterborough.*

"Ancillary Units—Memory and Time Delay Functions," *J. A. I. Young, Canadian General Electric Co. Ltd., Peterborough.*

"Ancillary Units—Power Amplification Functions," *J. S. MacKelvie, Canadian General Electric Co. Ltd., Peterborough.*

Reliability Requirements and Achievement in Design and Production

"The 'Project Mature' Concept of the Design and Production Requirements for Reliable and Maintainable Military Electronic Equipment," *C. I. Soucy, Royal Canadian Air Force, Ottawa.*

"Animal or Mineral?—A Study of Defect Causes," *J. J. Fitzsimons, Canadian Marconi Co. Montreal.*

"Why An Environmental Laboratory?" *J. S. Brooks, RCA Victor Co. Ltd., Montreal.*

"Variables Sampling as Applied to the Acceptance of Electrical Components," *E. C. Longhurst, RCA Victor Co. Ltd., Montreal.*

Broadcast and Transmission

"Trans-Canada Television Facilities Video Interconnecting Facilities," *P. J. Burman, Bell Telephone Co. of Canada, Montreal.*

"A Portable Broad-Band Power Density Meter," *A. Borck, Empire Devices Inc., New York.*

"Special Effects Generator," *W. E. Jeynes, Niagara Television Ltd., Hamilton.*

"Packaged Civil Defence Trans-Portable Broadcasting System," *H. Z. Rogers, Canadian General Electric Co. Ltd., Toronto.*

"A Broad-Band Data Transmission Link for Use with Radar," *J. Humphries and W. C. Brown, National Research Council, Ottawa.*

Propagation

"Ionospheric Equipment for High Power, High Resolution Studies of the Ionosphere in the Frequency Band," *D. Covill and R. Hanley, Cossor (Canada) Ltd., Halifax.*

"Ionospheric Studies at Oblique Incidence Over a 600-Mile Circuit," *G. W. Jull and W. L. Hatton, Defence Res. Board, Ottawa.*

"Effect of Mountains with Smooth Crests on Wave Propagation," *I. P. Shkarofsky, H. E. J. Neugebauer, and M. P. Bachynski, RCA Victor Co. Ltd., Montreal.*

"A Perforated Disk for Microwave Sector Scanning," *R. H. T. Bates, Canadian Westinghouse Co. Ltd., Hamilton.*

"Investigation of the Drifts of the Effective Point of CW Radio Reflection Along a Meteor Train," *M. S. Rao and R. L. Armstrong, National Res. Council, Ottawa.*

Thursday Morning, October 9

Aircraft Electronics

"Range Prediction for Infra-Red Detection Systems," *M. S. Juzycz, Avro Aircraft Ltd., Toronto.*

"Transistorized Analog to Digital Converter for Airborne Applications," *W. G. Thistle, Defence Res. Board, Quebec.*

"A Tumbling Low Drain Distress Beacon for Aircraft Crash Location," *D. M. Makow and T. H. Stevinson, National Res. Council, Ottawa.*

"A Magnetic Amplifier Voltage Regulator for an Aircraft Electrical System," *D. R. Joyce and H. G. Pinder, Canadian Westinghouse Co. Ltd., Hamilton.*

"Origin and Significance of Electrical Power Supply Transients in Aircraft," *C. Boot, Avro Aircraft Ltd., Toronto.*

Industrial Electronics II

"Oscillographs and Experimental Stress Analysis," *W. C. Leith, Dominion Engineering Works Ltd., Montreal and B. H. McGregor, A. C. Wickman Ltd., Toronto.*

"The Application of Transistor Logic Circuits to Industrial Electronic Control Problems," *W. H. Glaister, Canadian Westinghouse Co. Ltd., Hamilton.*

"*Linatrol Automatic Tracing for Gas Cutting Machines,*" *J. S. Cheverton, Canadian Westinghouse Co., Ltd., Hamilton.*

"Measurement of Strip Elongation in a *Steel Temper Mill,*" *G. F. Kelk and J. Taushman, George Kelk Ltd., Toronto.*

"A Transistorized Fail Safe Alarm-Cage Phone for Mines," *P. L. Hazan and D. G. W. Mace, Canadian Westinghouse Co. Ltd., Hamilton.*

Education—Panel Discussion on the Balance Between Theory and Practice in Engineering Education

Panel Members:

A. Porter, Dean of Eng., University of Saskatchewan, Saskatoon, Saskatchewan.

W. F. McMullen, Eng. Personnel Manager, Canadian General Electric Co. Ltd., Peterborough.

Two other members to be announced.

Medical Electronics I

"The Electronic Recording of Eye Movements," *W. Johnson and N. R. Winter, Defence Res. Medical Labs., Toronto.*

"Design for Electronic Controls for Weak or Paralyzed Muscles," *J. V. Basmajian, Dept. of Anatomy, Queen's University, Kingston.*

"Stable Band-Pass Filters for Electroencephalography," *W. R. D. Ross and J. F. Davis, Allan Memorial Inst. of Psychiatry, Montreal.*

"Neurosonic Surgery," *W. J. Fry, Biophysical Res. Lab., University of Illinois, Urbana, Ill.*

"Measurement of Photocell Stability," *W. Paul, Dept. of Pathological Chemistry, University of Toronto, Toronto.*

Antenna Design

"CF 105 Antenna Design," *F. G. Buckles, Sinclair Radio Labs. Ltd., Toronto.*

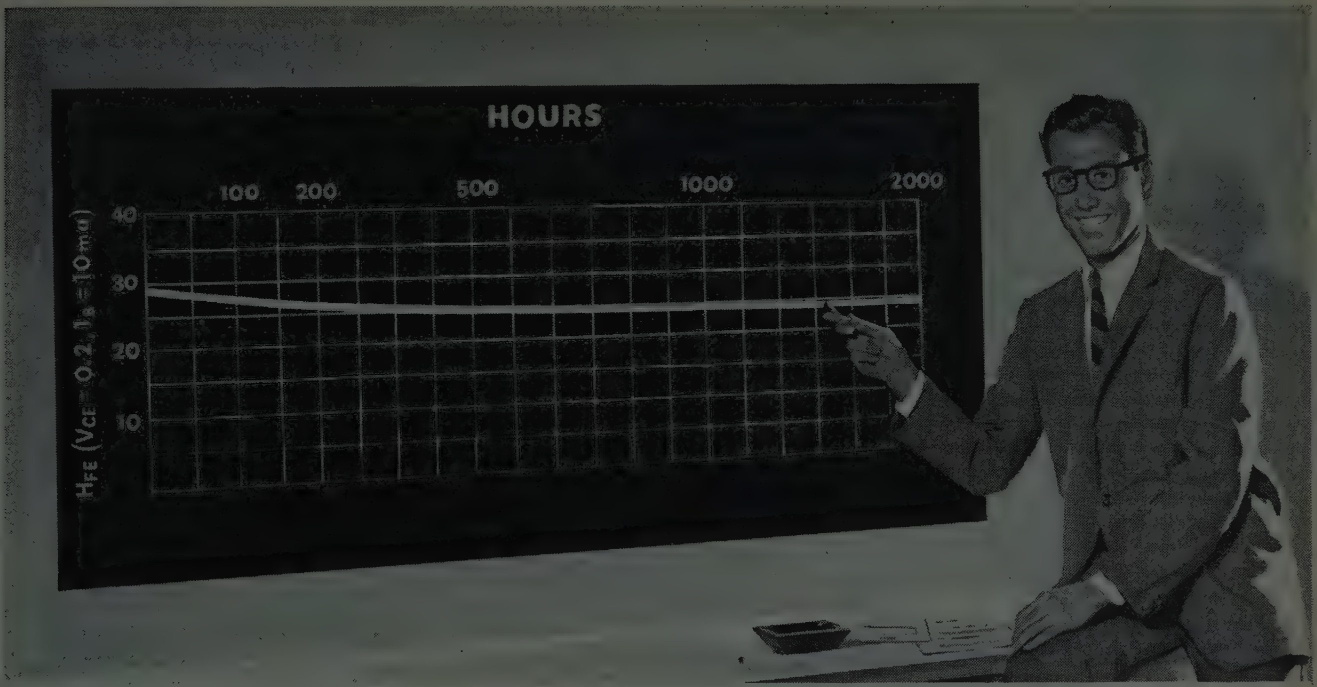
"The Design and Construction of a 60-Foot Paraboloidal Antenna," *D. T. Wright and A. E. Fentiman, Eng. Dept., Queen's University, Kingston.*

"Ten Foot Diameter Parabolic Antennas for 400 MC," *R. P. Matthews, Andrew Antenna Corp. Ltd., Whitby, Ontario.*

"Analysis and Reduction of Scattering from the Feed of a Cheese Antenna," *W. A. Cumming and S. C. Loh, National Res. Council, Ottawa, and C. P. Wang, Stanford University, Stanford, Calif.*

"Two Methods of Improving the Performance of Lens Corrected H-Plane Horns," *J. A. Cummins, Canadian Armament Res. and Dev. Establishment, Valcartier, Quebec.*

SYLVANIA–NPN SWITCHING TRANSISTORS

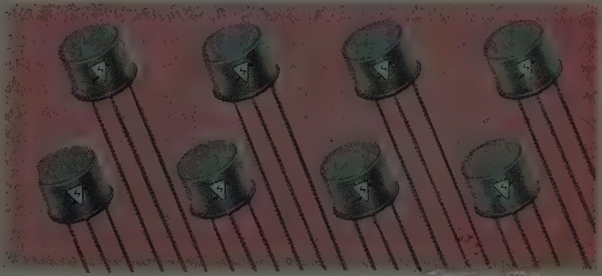


...still holding the line at 2000 hours

Eight new high stability NPN switching transistors designed for wide application in low and medium power switching circuits, are now available from Sylvania. They increase to 15, the total number of NPN switching types in the Sylvania line. Most of the units now have passed 2,000-hour evaluations and are continuing to maintain the high Beta stability and fast rise time so important in switching applications.

The fifteen NPN germanium transistors include both *base-on-the-can* types with *150 mw and 200 mw dissipation* and *base-off-the-can* types with *100 mw dissipation*.

Each of the types features the Sylvania welded hermetic seal for full protection against humidity and other environmental conditions and meets JETEC TO-5 and TO-8 dimensions. For further particulars on the entire line, contact your Sylvania representative or write Sylvania direct.



NEW

Type	Max. Dissipation at 25° Ambient	Max. Junction Temp. (°C)	Max. I_c (ma)	Current Gain h_{FE}	Max. Rise Time, t_r
2N439	100 Mw	85	100	40	2.5 usec
2N556	100 Mw	85	200	50	3.5
2N557	100 Mw	85	200	30	6.5
2N558	100 Mw	75	200	75	3.5
2N576*	200 Mw	100	400	40	2.0
2N576A*	200 Mw	100	400	60	2.0
2N587*	150 Mw	85	200	30	2.0
2N679*	150 Mw	85	100	20	3.0
2N312	100 Mw	185	200	20	1.5
2N356	100 Mw	85	500	30	2.0
2N357	100 Mw	85	500	30	1.2
2N358	100 Mw	85	500	30	0.8
2N377*	150 Mw	100	200	40	2.5
2N385*	150 Mw	100	200	70	–
2N388*	150 Mw	100	200	110	1.0

*Base internally connected to the case

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Thursday Afternoon

Stereophonic Disk Recording and Audio

"Tracing Distortion in Stereophonic Disk Recording," *M. S. Corrington, Radio Corp. of America, Camden, N. J.*

"Certain Problems and Solutions in the Recording and Reproduction of Stereophonic Disks," *B. B. Bauer, Columbia Broadcasting System Labs., New York.*

"Design Consideration in the Use of the Stereophonic Disk Cartridge," *H. Durbin, Electrovoice, Buchanan, Mich.*

"Effect of Preamplifier Input Impedance on Broadcast Quality Microphone Characteristics," *A. Jamroz, Northern Electric Co., Belleville, Ontario.*

Semiconductor Theory and Measurement

"Photo-Impedance of Semiconductor Barriers and Junctions," *H. W. Jaderholm, Canadian Marconi Co., St. Sauveur des Monts, P.Q.*

"The Hall Effect and Some of Its Possible Applications," *C. H. Champness, Northern Electric Co. Ltd., Montreal.*

"Transistor Parameter at Liquid Nitrogen Temperatures," *R. W. Jackson, RCA Victor Co. Ltd., Montreal.*

"Some High Frequency Measurements on Drift Transistors," *J. Almond, RCA Victor Co. Ltd., Montreal.*

"Thermal, Shot and IF Noise in Junction Transistors," *J. M. Stewart, RCA Victor Co. Ltd., Montreal.*

Communication Systems

"Equipment Considerations on the Quebec-Labrador Tropospheric Scatter Radio System," *H. H. Pelletier, Bell Telephone Co. of Canada, Montreal.*

"Equipments for Measuring Intermodulation Distortion on Radio Links Carrying Multichannel Telephony," *L. Slaven, RCA Victor Co. Ltd., Montreal.*

"The Application of Negative Impedance Amplifiers to Conference Circuits," *E. S. Kelsey and E. H. Lanham, Northern Electric Co. Ltd., Montreal.*

"Radio Relay Systems in the Province of British Columbia," *M. E. Green, British Columbia Telephone Co., Vancouver.*

"Distortion and Interference Effects in HF Single Sideband," *D. E. Gerrior, Collins Radio Co. of Canada Ltd., Toronto.*

Cosmic Radiation

"Cosmic Radiation and Its Origin," *H. Carmichael, Atomic Energy of Canada Ltd., Chalk River, Ontario.*

"Intensity Variations in Cosmic Rays," *D. C. Rose, National Res. Council, Ottawa.*

"Cloud Chamber Counter Selection Systems Used in the Study of Cosmic Rays," *I. B. McDiarmid, National Res. Council, Ottawa.*

"The Identification of Cosmic Ray Particles Using Cerenkov Detectors," *M. Bercovitch, Atomic Energy of Canada Ltd., Chalk River, Ontario.*

"Automatic Counting and Pulse Height Analysis for Cosmic Rays," *J. F. Steljes, Atomic Energy of Canada Ltd., Chalk River, Ontario.*

Circuit Theory

"An Operational Calculus Formula with Applications to FS and FM Transient Response," *E. S. Kelsey, Northern Electric Co. Ltd., Montreal.*

"Direct Analysis of Electrical Networks Through Signal Flow Graphs," *L. P. A. Robichaud, Canadian Armament Res. and Dev. Establishment, Valcartier, Quebec.*

"Some New Results Concerning Twin-T Networks," *M. Price, Computing Devices of Canada Ltd., Ottawa.*

"A Pitfall to Avoid when Using Thevenin's or Norton's Theorems," *M. P. Beddoes, University of British Columbia, Vancouver.*

"An Optical Hybrid Junction for Millimeter Wavelengths," *R. M. Vaillancourt, Canadian Armament Res. and Dev. Establishment, Valcartier, Quebec.*

Friday Morning, October 10

Transistor Circuit Design

"A Design Procedure for High Level Transistor Wide Band Amplifiers," *C. R. Zimmer, L. C. Smith College of Eng., Syracuse University, Syracuse, N. Y.*

"The Charge Storage in a Junction Transistor During Turn Off in the Active Region," *R. S. C. Cobbold, Defence Res. Board, Ottawa.*

"A Simple Design Technique for High Performance Transistor AC Amplifiers," *D. G. W. Mace and R. N. Blunt, Canadian Westinghouse Co. Ltd., Hamilton.*

"Factors Affecting the Nonlinearity of Transistor Amplifiers," *G. W. Holbrook and B. A. Bowen, Royal Military College of Canada, Kingston.*

"Amplitude Distortion in Transistor Amplifiers," *J. Hanson, Sinclair Radio Labs. Ltd., Toronto.*

Astronautics

"Radio Observations of Sputnik I," *E. L. R. Webb and A. G. McNamara, National Res. Council, Ottawa.*

"Experimental Lunar Antenna," *M. Valeriote and P. T. Valeriote, Canadian Astronautical Society, Downsview, Ontario.*

"The Search for a National Radio Astronomy Observation Site," *C. F. Pattenson and N. W. Broten, National Res. Council, Ottawa.*

Engineering Writing and Speech

"Write to Inform, Not to Impress," *L. W. Billingsley, Defence Res. Board, Ottawa.*

"On Teaching Engineers How to Write Effectively," *E. R. Charles, Ryerson Inst. of Tech., Toronto.*

"Formulation of a Tri-Service Specification for Test Equipment Manuals," *J. R. Simpson, Electronic Associates Ltd., Willowdale, Ontario.*

"Let the Technical Journals Work With You," *I. R. Dutton, Canadian Electronics Engineering, Toronto.*

"Speech Preparation and Presentation," *H. L. Armstrong, Canadian General Electric Co. Ltd., Toronto.*

Medical Electronics II

"Electrocardiograph and Heart Rate Monitor Units Displaying Instantaneous Value of Heart Rate," *G. B. Richard and P. Sekelj, Biophysics Dept., Montreal Children's Hospital, Montreal.*

"A Zero Reference of Potential for Unipolar Electrocardiographic Leads," *G. E. Dower, A. D. Moore, and J. A. Osborne, University of British Columbia, Vancouver.*

"Vectorcardiography," *W. S. Martin, Respiratory Function Lab., Queen Mary Veterans Hospital, Montreal.*

"A New Computer for Three-Dimensional Electrocardiography," *G. E. Dower, A. D. Moore, W. K. R. Park, E. G. Poole, and J. Yuan, University of British Columbia, Vancouver.*

"Digital Techniques for Medicine," *M. W. Edinburg, Edin Company Inc., Worcester, Mass.*

Microwave Theory and Techniques

"An Iterative Numerical Method for Stagger-Tuning Multicavity Klystron Amplifiers," *B. A. Auld, A. T. Isaacs, and A. D. Moore, University of British Columbia, Vancouver.*

"A Microwave Frequency Synthesizer and Phase-Locked Klystron Frequency Stabilizer," *K. G. Schomandl, Munich, Germany.*

"A Low Power Amplitude Modulator at Microwave Frequencies," *C. Bowness, J. Owen, and N. E. Thomassen, Raytheon Canada Ltd., Waterloo, Ontario.*

"Ferrite Tunable Microwave Filters," *B. Vural, Canadian General Electric Co. Ltd., Toronto.*

"Quadruple-Diversity Reception and a Nonswitching Parallel Combiner," *S. S. Kostashuk, Northern Electric Co. Ltd., Belleville, Ontario.*

Friday Afternoon

Semiconductor Applications

"Use of Transistors in Low Temperature Noise Thermometry," *O. Celinski and D. K. C. MacDonald, University of Ottawa, Ottawa.*

"A Transistorized DC Power Supply Employing a Novel Method of Voltage Regulation," *E. E. Thompson, Canadair Ltd., Montreal.*

"High Speed Reversible Transistorized Counters," *J. D. Schmidt, General Electric Co., Syracuse, N. Y.*

"A Solid State Precision Computing Amplifier," *K. A. Turner, Honeywell Controls Ltd., Toronto.*

"A Transistorized Four-Channel Electronic Multiplex, Van Duuren Principle," *R. Zimmerman, Siemens & Halske Telegraph, Munich, Germany.*

Computers

"Computer Simulation of Economic Systems," *G. S. Glinski, University of Ottawa, Ottawa.*

"The Uses and Organization of an Analogue Computation Centre in a Large Electrical Manufacturing Firm," *W. S. Kozak, Canadian Westinghouse Co. Ltd., Hamilton.*

"Some Mechanical Aspects of an Analogue Computer," *J. E. Prosper, Canadian Arsenals Ltd., Toronto.*

"The Design of a Static Mark/Sense Reader," *W. Dingsdale, Ferranti Packard Ltd., Mount Dennis, Ontario.*

"High Speed-Paper Tape Reader for Military Use," *F. K. J. Goulding, Ferranti Packard Ltd., Mount Dennis, Ontario.*

Vehicular Communications

"Traffic Circulation on Long Distance Mobile Radio Telephone Networks," *G. Bedingham, Phillips Electronics Industries Ltd., Toronto.*

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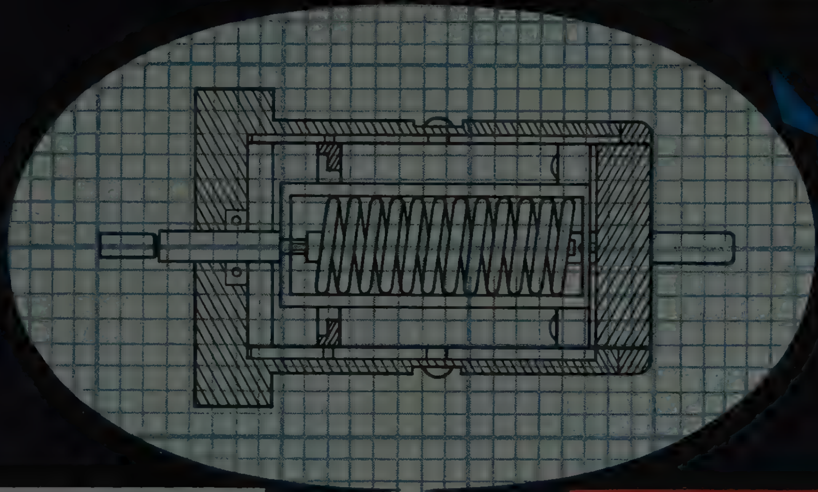

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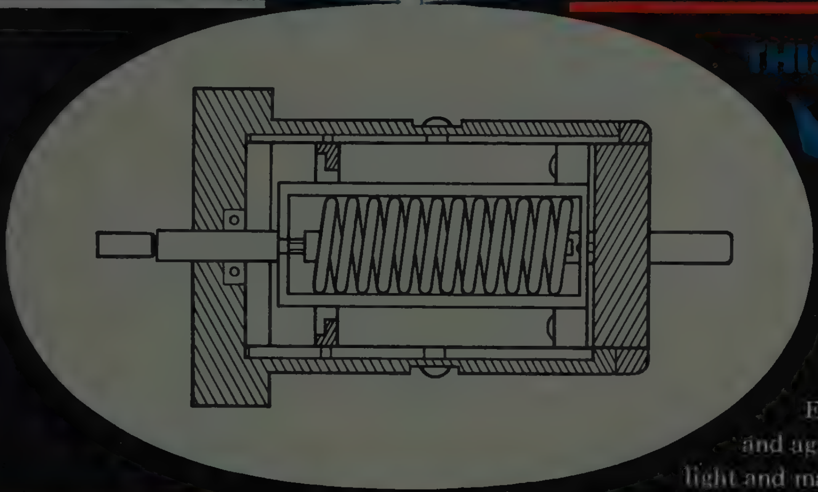

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Mobile Radio," *K. E. H. Backman, Motorola Inc., Chicago, Ill.*

" 'Diamond Taxi' Radio System Operating in Montreal," *P. R. G. Cahn, Canadian Marconi Co., St. Laurent, Quebec.*

"An Improved Design of 'Split Channel' Filters," *B. Tennent, Philips Electronics Industries Ltd., Toronto.*

Design Techniques

"A Rapid Technique for the Calculation of the Transient Response from the Frequency Response," *D. MacLachlan, Canadair Ltd., Montreal.*

"Some Practical Aspects of Strip Transmission Line Filter Design," *J. H. Craven, National Res. Council, Ottawa.*

"Graphical Solutions for Networks, Transistors and Transitron Oscillator Design," *V. Malolepszy, Canadian Aviation Electronics Ltd., Montreal.*

"A New Approach to Wide-Band Transformer Design," *A. C. Hudson, National Res. Council, Ottawa.*

"A Simplified Method for Designing Wide-Band High Precision 90° Phase-Networks," *R. M. Lerner, Mass. Inst. of Tech., Lexington, Mass.*

Microwave Systems

"Microwave Mirrors Conquer Mountainous Terrain," *D. E. Noble, Canadian Motorola Electronics Ltd., Toronto.*

"Microwave by Wire (G-Line)," *T. Hafner, Surface Conduction Inc., New York.*

"Microwave System Auxiliary Facilities Employing Digital Transmission," *D. S. Spendlove, Canadian Motorola Electronics Ltd., Toronto.*

"Performance and Equipment Considerations of a Modern 6000 MC Microwave System," *E. V. Hird and R. A. Marsh, Lenkurt Electric Co. of Canada Ltd., Vancouver, B.C.*

"A Frequency Diversity Over-Water Path at 2000 MC," *E. Pullan, M. Lopianowski, and S. R. Koblin, RCA Victor Co. Ltd., Montreal.*

Seventh Annual Conference on Industrial Electronics

SEPTEMBER 24–25, RACKHAM MEMORIAL BUILDING, DETROIT, MICHIGAN

The Seventh Annual Conference on Industrial Electronics will be held on September 24–25 in the Rackham Memorial Building in Detroit. IRE and AIEE are cosponsors.

Papers presented at the four technical sessions will cover applications of electronics in industrial problems, including processing, control, machine tool systems and devices, transducers, welding, and electronic and transistorized circuits.

Walter P. Reuther, President, United Automobile Workers, C.I.O., will speak on "Labor Views Industrial Automation," at a luncheon on September 24. The following day Dr. Irven Travis, Vice-President, Research and Engineering, Burroughs Corporation, will present the views of management on the same topic.

Wednesday Morning—September 24

Electronics Applied to Machine Tools

"The Building Block Approach to Industrial Control Systems," *H. L. Shoemaker, Hughes Aircraft Co.*

"The Numerically Controlled Manufacturing System," *F. E. Booth, Bendix Aviation Corp.*

"A Positioning Servo for Automatic Machine Tool Operation," *F. H. London, Airborne Instruments Lab., Inc.*

"An Automatically Controlled Vertical Turret Lathe," *A. O. Fitzner, Giddings and Lewis Tool Co.*

Wednesday Afternoon

Electronics Applied to Industrial Processes

"Automatic Packaging of Gelatin Capsules," *S. H. McMillan, Strand Engineering Co.*

"Semiautomatic Stud-Welding Equipment," *J. F. Stewart, Radio Corp. of America.*

"Electronics in Automatic Mail Cancelling and Facing," *H. Goldberg, Emerson Radio and Phonograph Corp.*

"A Two-Dimensional Tracer Control System," *R. W. Capron, Bendix Aviation Corp.*

Thursday Morning—September 25

Electronics Related to Testing

"Automatic Hardness Tester," *R. B. Allured, General Motors Corp.*

"Pulse-Time Positioning Used for Safety Control of High Speed Tester," *M. E. Fitch, Ford Motor Co.*

"Multichannel Swept Sonic Tester for Casting Quality Control," *N. W. Schubring, General Motors Corp.*

"Modular Automatic Test Equipment Minimizes Production Costs," *H. Rose and J. Tampico, American Machine and Foundry Co.*

Thursday Afternoon

Components and Devices for Industrial Electronics

"Design of High-Performance Instrument Servos for General-Purpose Computation," *K. V. Bailey and M. A. Ziniuk, Bendix Aviation Corp.*

"The Cunningham Crossbar Switch," *K. Enslein, Brooks Research, Inc.*

"Nuclear Reactor Control System," *D. J. Niehaus, R. R. Hoge, and A. B. Van Rennes, Bendix Aviation Corp.*

"Philosophical Aspects of Instrument Performance," *W. G. Deutsch, Panellit, Inc.*

Eighth Annual Broadcast Symposium

SEPTEMBER 26–27, WILLARD HOTEL, WASHINGTON, D. C.

On September 26–27, the Eighth Annual Broadcast Symposium will be held at the Willard Hotel in Washington, under the sponsorship of the Professional Group on Broadcast Transmission Systems.

In addition to ten outstanding technical papers, the symposium will feature a conducted tour of an NBC color television plant, and a panel discussion of videotape operation at which three major networks will be represented.

A cocktail party and banquet will conclude the first day of the meeting. George W. Bailey, Executive Secretary of the IRE, will be toastmaster at the banquet, and the guest speaker will be Commissioner T. A. M. Craven of the Federal Communications Commission.

Registration for the Symposium begins at 9:00 A.M. on September 26.

Friday Morning—September 26

Introductory Remarks, *C. H. Owen, Chairman PGBTS, American Broadcasting Co.*

Moderator, *R. F. Guy, National Broadcasting Co.*

"Present Switching Facilities," *R. W. Rodgers, Westinghouse Broadcasting Co.*

"Very Precise Carrier Offset as a Function of Television Cochannel Interference," *Author to be announced, Federal Communications Commission.*

"Chroma-Key System," *R. Kennedy, National Broadcasting Co.*

"Handling the Dark Current in Vidicons and Vidicon Operating Techniques," *J. H. Roe, Radio Corp. of America.*

Friday Afternoon

Conducted Tour of the New WRC-TV Color Television Plant, *D. Castle, National Broadcasting Co.*

Saturday Morning—September 27

"Stereophonic Broadcasting," *M. G. Crosby, Crosby Labs.*

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P_C	Total dissipation Case temp. 25° C. Case temp. 100° C.	 2 watts 1 watt		
h_{FE}	D.C. current gain		2N696—15 to 30 2N697—30 min.	I_C=150ma V_C=10v
R_{CS}	Collector saturation resistance		6Ω typical, 10Ω max.	I_C=150ma I_B=15ma

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"Uses of Transistors in Video with Special Emphasis on Transistorized Switching," *A. C. Luther and J. W. Wentworth, Radio Corp. of America.*

"Weather Radar in TV Broadcasting," *Author to be announced.*

"FM and Multiplex," *A. H. Bott, Radio Corp. of America.*

Saturday Afternoon

Moderator, *R. N. Harmon, Westinghouse Broadcasting Co.*

"NBC—Burbank Color Videotape Plant," *R. Byloff, National Broadcasting Co.*

"CBS—New York Videotape Facilities," *K. B. Benson and P. E. Fish, CBS Television.*

Panel Discussion of Videotape Operational Experiences, *R. M. Morris, Chairman, American Broadcasting Co.; L. Weiland, National Broadcasting Co.; K. B. Benson, CBS Television; J. L. Middlebrooks, Station KING-TV, Seattle, Wash.*

Second National Symposium on Engineering Writing and Speech

OCTOBER 1–2, HOTEL BILTMORE, NEW YORK, NEW YORK

The Professional Group on Engineering Writing and Speech will sponsor its second national symposium in New York on October 1–2 at the Hotel Biltmore.

Fourteen papers have been scheduled on the techniques and problems of communicating technical material to a reading or listening audience.

A special feature of the meeting will be a luncheon address on October 1 by Dr. George H. Brown, Chief Engineer at RCA's Industrial Electronic Products Division, Camden, N. J.

The symposium committee includes J. D. Chapline, Chairman; T. T. Patterson, Jr., and C. W. Sall, Program; H. B. Michaelson, Finance; W. A. Stocklin, Arrangements; E. B. Palmquist, Publicity; and E. M. McElwee, Secretary.

Registration fee, payable at the hotel, is $5.00.

Wednesday—October 1

Registration.

Session I

"How to Murder an Audience," *S. J. Mason, Massachusetts Institute of Technology, Cambridge, Mass.*

"Microphone Techniques," *P. Taylor, WRCV-NBC, Philadelphia, Pa.*

"Can They See What You Say When You Speak?" *E. W. Still, General Electric Co., Utica, N. Y.*

Session II

"Writing and Speaking Techniques," *R. E. Clarke, Nelson Technical Enterprises, St. Charles, Ill.*

"The Function and Design of the Scientific Message," *H. F. Arader, University of Pennsylvania, Philadelphia, Pa.*

"Selecting and Writing to the Proper Level," *J. Racker, Caldwell-Clements Manuals Corp., New York, N. Y.*

"Engineering Writing 'Up or Down'," *M. L. Feistman, Westinghouse Electric Corp., Baltimore, Md.*

Thursday—October 2

Registration.

Session III

"Portrait of a Presentation," *M. Stewart, Ewing Technical Design, Inc., Philadelphia, Pa.*

"Running Your Own Projector," *J. B. Angell, Philco Corp., Philadelphia, Pa.*

"Use Your Reader's Eyes," *P. M. Beatts, IBM Corp., Poughkeepsie, N. Y.*

"Planning Illustrations First Simplifies Writing Later," *F. H. Rockett, McGraw-Hill Book Co., Inc., Charlottesville, Va.*

Session IV

"IRE Publications—The Section Bulletin," *A. L. Cotcher, Cubic Corp., San Diego, Calif.*

"How To Be a Dictator," *J. D. Chapline, Philco Corp., Philadelphia, Pa.*

"Word Simplicity," *F. V. Long, Texas Eastern Transmission Corp., Shreveport, La*

National Symposium on Extended Range and Space Communications

OCTOBER 6–7, LISNER AUDITORIUM, GEORGE WASHINGTON UNIVERSITY, WASHINGTON, D. C.

George Washington University will be host to the National Symposium on Extended Range and Space Communications on October 6–7. The University is also cosponsoring the event with the Professional Groups on Communications Systems and Antennas and Propagation. Although expanded to include space communications, the symposium will be similar in scope to the first National Scatter Symposium held three years ago.

An invited survey paper, designed to review general progress and to coordinate the subject material of the succeeding papers, will be presented at the beginning of each of the technical sessions.

There will be an informal dinner at the Roger Smith Hotel on October 6, followed by a joint meeting with the Washington Section of IRE.

Advance registration for IRE members is $3.50; for nonmembers, $4.00. Registration during the meeting will be fifty cents additional. There will be no registration fee for students. Members of the two sponsoring IRE Professional Groups will receive forms for advance registration by mail. These forms may also be obtained from W. Balwanz, Code 5323B, Naval Research Laboratory, Washington 25, D. C.

Monday Morning—October 6

Opening Address, *M. A. Mason, Dean, George Washington University.*

Introductory Remarks, *H. Fine, Symposium Chairman, Federal Communications Commission.*

Space Transmission Problems

"Space Environment Controls Communications Capability," (invited), Maj. E. N. Wright, Hdqs., Air Res. and Dev. Command.

"Space Vehicle Television," *C. P. Sonett, The Ramo-Wooldridge Corp.*

"Some Aspects of Using Space Satellites as Passive Reflectors for Communication Purposes," *D. C. MacLellan, Lincoln Lab., M.I.T.*

"Optimum Frequencies for Space Vehicle Communications," *S. Perlman, L. C. Kelley, W. J. Russell, Jr., and W. D. Stuart, U. S. Army Signal Radio Propagation Agency.*

"Shockwave Ionization and Its Effect on Space Communications," *W. B. Sisco and J. M. Fiskin, Douglas Aircraft Co., Inc.*

Monday Afternoon

Meteor Burst Communication Systems

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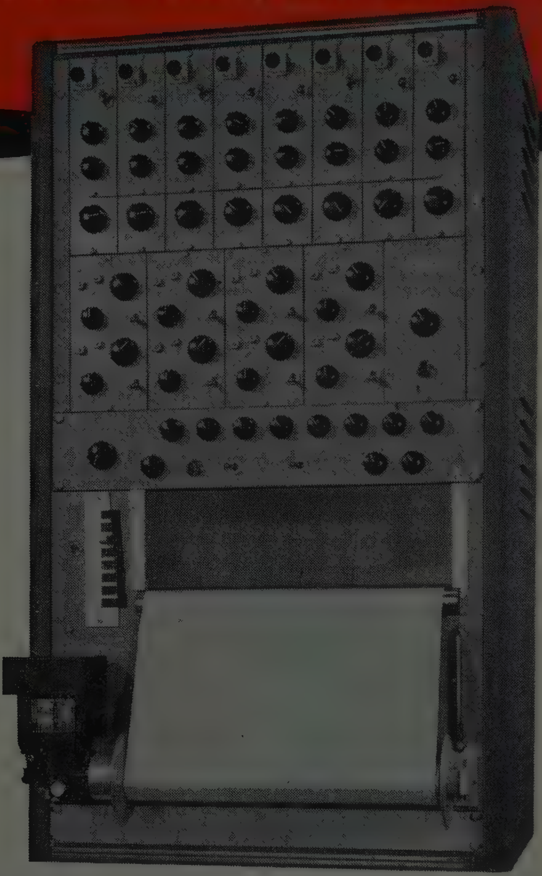

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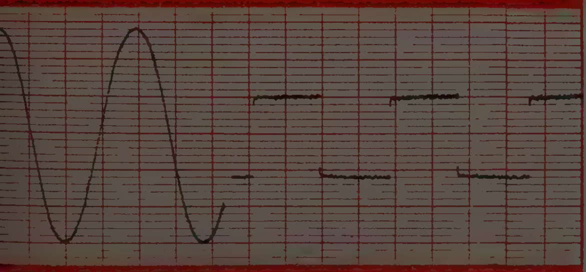

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(invited), *A. M. Peterson and W. R. Vincent, Stanford Res. Inst.*

"Development of Meteor Burst Communication Systems for the Navy," *H. E. Chubb, U. S. Navy Electronic Lab.*

"Multipath Limitations in Meteor-Burst Communication," *G. R. Sugar, National Bureau of Standards.*

"Wideband Facsimile Transmission Over a 900-Mile Path Utilizing Meteor Ionization," *W. H. Bliss, R. J. Wagner, Jr., and G. S. Wickizer.*

"An Appraisal of Meteor Burst System Performance," *E. E. Reinhart, RAND Corp., and D. C. Ports, Jansky and Bailey.*

Tuesday Morning—October 7

Extended Range Tropospheric Communication Systems

Chairman, *J. H. Chisholm, Lincoln Lab., M.I.T.*

"Status of Tropospheric Extended Range Transmission" (invited), *K. M. Bullington, Bell Telephone Labs.*

"Discussion of Results From a Three-Hop Tropospheric Scatter Link in Norway With Parallel Operation on 1000 MC and 2000 MC," *N. H. Knudtzon and P. E. Gudmandsen, SHAPE Air Defense Technical Center.*

"Tropospheric Scatter Path Loss Tests, Florida-Bahamas," *K. P. Stiles, American Telephone and Telegraph Corp.*

"Performance of a 640-Mile, 24-Channel UHF-SSB Communication System (AN/FRC-47)," *B. E. Nichols, Lincoln Lab., M.I.T.*

"Experimental Measurements of Angular Diversity System at 2000 MC," *J. H. Chisholm and J. F. Roche, Lincoln Lab., M.I.T.*

Tuesday Afternoon

Extended Range Ionospheric Communication Systems

Chairman, *R. Bateman, Page Communications Engineers, Inc.*

"A Survey of VHF Ionospheric Extended Range Transmission" (invited), *R. C. Kirby, National Bureau of Standards.*

"The Performance of ARQ Telegraph Equipment on Ionospheric Scatter Teletype Circuits," *S. Browne, SHAPE Air Defense Technical Center.*

"An Experimental Equipment to Reduce Teleprinter Errors in the Presence of Multipath," *J. L. Hollis, Rixon Electronics, Inc.*

"Performance of an Experimental Anti-Multipath Equipment on an Ionospheric-Scatter Path," *G. E. Boggs, Page Communications Engineers, Inc.*

"Modulation Studies for VHF Ionospheric Scattering," *J. W. Koch, National Bureau of Standards.*

Professional Groups†

Aeronautical & Navigational Electronics—G. L. Haller, G. E. Co., Electronic Park, Syracuse, N. Y.

Antennas & Propagation—R. L. Mattingly, Bell Tel. Labs., Whippany, N. J.

Audio—F. H. Slaymaker, Stromberg-Carlson, 1400 N. Goodman St., Rochester 3, N. Y.

Automatic Control—J. E. Ward, Servomechanisms Lab., M.I.T., Cambridge 39, Mass.

Broadcast & Television Receivers—H. A. Bass, Avco Mfg. Corp., Arlington, Cincinnati, Ohio.

Broadcast Transmission Systems—C. H. Owen, 7 W. 66th St., N. Y. 23, N. Y.

Circuit Theory—W. H. Huggins, 2813 St. Paul St., Baltimore 18, Md.

Communications Systems—E. N. Dingley, Jr., Electronic Communications Inc., 1501 72 St., N., St. Petersburg, Fla.

Component Parts—P. S. Darnell, Bell Tel. Labs., Whippany, N. J.

Education—R. L. McFarlan, 20 Circuit Rd., Chestnut Hill 67, Mass.

Electron Devices—G. R. Kilgore, Westinghouse Elec. Corp., Baltimore, Md.

Electronic Computers—W. H. Ware, Rand Corp., 1700 Main St., Santa Monica, Calif.

Engineering Management—G. A. Rosselot, Bendix Aviation Corp., Box 5115, Detroit 35, Mich.

Engineering Writing and Speech—J. D. Chapline, Philco Corp., Tioga and C Sts., Philadelphia, Pa.

Human Factors in Electronics—H. P. Birmingham, U. S. Naval Research Lab., Washington 25, D. C.

Industrial Electronics—W. R. Thurston, General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

Information Theory—T. P. Cheatham, Melpar Inc., 43 Leon St., Boston, Mass.

Instrumentation—L. C. Smith, Hycon Eastern Inc., 75 Cambridge Pkwy., Cambridge 42, Mass.

Medical Electronics—Urner Liddel, Physical Biology Dept., National Inst. of Health, Bethesda, Md.

Microwave Theory and Techniques—T. S. Saad, Sage Labs., Inc., 159 Linden St., Wellesley 81, Mass.

Military Electronics—E. A. Speakman, RCA Defense Electronic Products, Camden, N. J.

Nuclear Science—A. B. Van Rennes, Bendix Aviation Corp., Box 5115, Detroit 35, Mich.

Production Techniques—L. M. Ewing, General Electric Co., W. Genesee St., Auburn, N. Y.

Radio Frequency Interference—H. R. Schwenk, Sperry Gyroscope Co., Great Neck, L. I., N. Y.

Reliability and Quality Control—P. K. McElroy, General Radio Co., 22 Baker St., West Concord, Mass.

Telemetry and Remote Control—C. H. Doersam, Jr., Sperry Gyroscope Co., Great Neck, L. I., N. Y.

Ultrasonics Engineering—J. E. May, Jr., Bell Tel. Labs., Whippany, N. J.

Vehicular Communications—A. A. MacDonald, Motorola, Inc., 4545 W. Augusta Blvd., Chicago 51, Ill.

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† Names listed are Group Chairmen.

Sections*

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Anchorage—William K. McCaskill, P.O. Box 4853, Spenard, Alaska; Arthur Borisky, Jr., Box 1519, Anchorage, Alaska. (Temporary.)

Atlanta (3)—E. G. Holmes, 309 Pharr Rd., N.E., Rm. 9, Atlanta, Ga.; R. L. Ellis, Jr., 77 Karland Dr. N.W., Atlanta, Ga.

Baltimore (3)—P. A. Hoffman, Hoover Electronics Co., 110 W. Timonium Rd., Timonium, Md.; F. K. Clark, Jr., 5722 Northwood Dr., Baltimore 12, Md.

Bay of Quinte (8)—M. J. Waller, R.R. 1, Foxboro, Ont., Canada; Robert Williamson, R.R. 3, Beleville, Ont., Canada.

Beaumont-Port Arthur (6)—T. G. Powers, 3558 Taylor Dr., Lake Charles, La.; H. K. Smith, 270 Canterbury Lane, Beaumont, Tex.

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Kitchener-Waterloo (8)—J. M. Duvall, 49 Sandra Ave., Kitchener, Ont., Canada; G. C. Field, 48 Harbor Ave., Kitchener, Ont., Canada.

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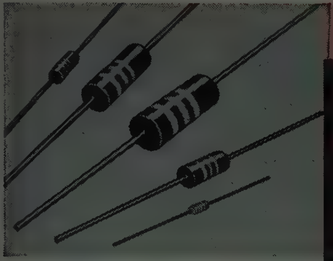

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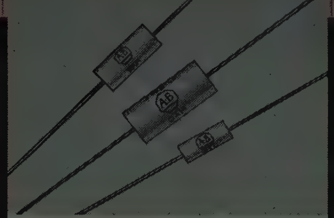
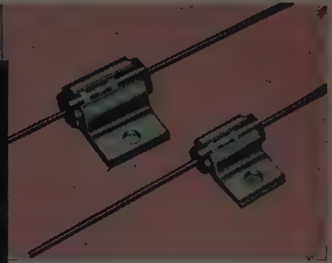
HERMETICALLY SEALED in ceramic tubes. Solid, hot molded resistor. Less than 1% resistance change after 250 hr, 95% rel. hum., 40°C. Resistance values to 22 megohms.

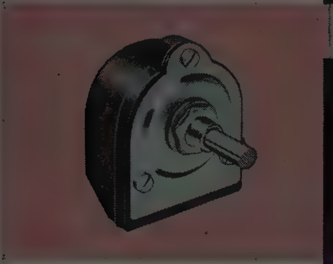


METAL GRID PRECISION RESISTORS—Hermetically sealed. Non-inductive. 1, 1/2, And 1/4 watts at 100°C. Tolerances 0.1% to 1.0%. Temp coef. ± 25 PPM/°C.

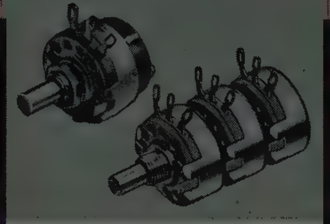


COPPER CLAD—Metal panel mounting, insulated composition resistor supplied in two ratings: 3 and 4 watts at 70°C, and 4 and 5 watts respectively at 40°C.

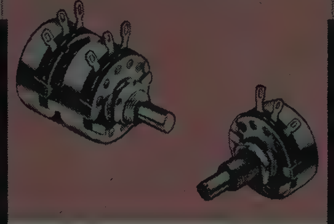
POTENTIOMETERS



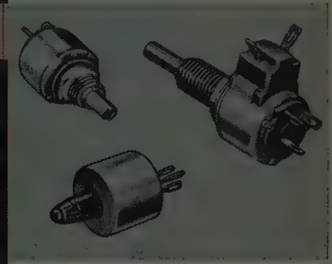
INDUSTRIAL—Type H with solid, hot molded resistor element. Quiet, improves with use. Life over 100,000 cycles. Rated 5 watts, 40°C; and 3 watts, 70°C.



STANDARD—Type J. Solid molded element. Quiet, reliable. Rated 2 watts, 70°C. Values to 5 meg.—less than 10% change in 100,000 cycles. Exceeds MIL-R-94B.



HIGH TEMPERATURE—Type K. Similar to Type J but rated 3 watts, 70°C; 2 watts, 100°C; and 1 watt, 125°C—derate to zero at 150°C. Many types and tapers.

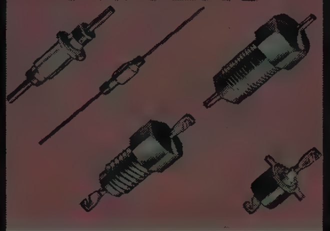


MINIATURE—Type G. Solid molded element. Only 1/2" in diam. Plain or lock bushing; also with line switch. Rated 0.5 watt at 70°C. Values to 5 megohms.

FERRITES

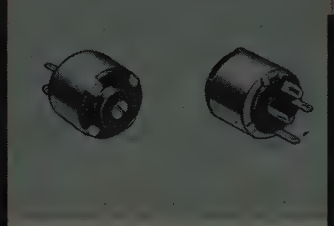
TV CORES, including lightweight flared yokes; U, L, and O cores for color convergence; U and E flyback cores; and others. All have uniform magnetic properties.

FILTERS



HIGH FREQUENCY low pass cascaded ceramic filters for elimination of radiation. Max ratings: 500 v DC at 125°C; RF current 0.25 amp; DC or LF current 5 amp.

POTENTIOMETERS

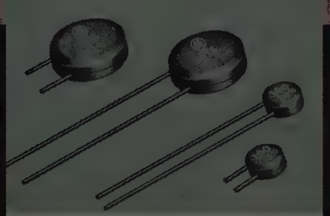


PRINTED CIRCUIT TYPE—Solid molded element. Rated 1/4 watt at 70°C. Type F is only 1/2" in diam. Screwdriver adjustment. Total resistance values to 5 meg.

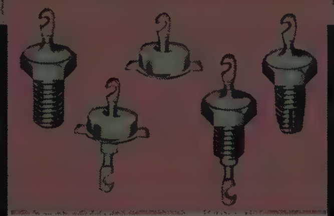
THIN TYPE—Uses molded cover as actuator. Type T has solid molded element. Rated 1/2 watt at 70°C. Life in excess of 50,000 cycles. Total values to 5 megohms.

CAPACITORS

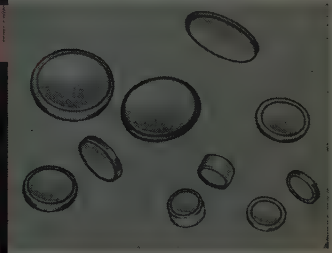
CERAMIC DIELECTRIC capacitors of superior quality, in a wide variety of types—GP (single and dual)—with no "rundown" on leads. Also, as TC and stable.



CERAMIC ENCASED capacitors for use where reliability and superior performance at high temp are important. Rated 500 v DC at 150°C. Tol: 5%, 10%, and 20%.



FEED-THRU & STAND-OFF discoidal capacitors for VHF and UHF range. No parallel resonance effects at 1,000 Mcps or less. Nominal values 4.7 to 1,000 mmf.



BARE DISC ceramic capacitors for direct mounting in printed circuit boards. Mechanically strong to avoid breakage in handling, installing, and soldering.

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QUALITY
ELECTRONIC COMPONENTS

"УДИВИТЕЛЬНО!"*

CONTROL is first! Now—one step static control with switching reactors

No wonder Nikita looks worried. CONTROL has taken the strain off American industry's pocketbook by cutting the cost of static control.

American engineers who want to make free use of power switching guided by digital logic can now take over, because CONTROL's standard line of switching reactors give freedom of design and economy never before available.

First, one-step static control with switching reactors is so easy to operate it can be put to work in everyday sequencing and switching problems involving either a-c or d-c loads. Auxiliary equipment is eliminated by the basketful. Gone are all the preamplifiers, special power supplies, information-sorting single purpose logic units, and power switching relays. CONTROL's one-step switching reactor does most of the job by itself.

Second, these units, in four nominal volt-ampere ratings of 15, 75, 150 and 300, have no relay contacts or moving parts to replace. Switching is by impedance change. Install them and forget them—no wear, no maintenance.

Third, each CONTROL reactor performs all logic functions —AND, OR, NOT, MEMORY and TIME DELAY—through its multipurpose control coils. Signal source is derived typically from limit switches, push buttons, or photo-cells.

Fourth, each unit has a 10,000:1 switching ratio under nominal supply voltage conditions. High inrush currents are handled without difficulty.

To learn how CONTROL reactors work, and how they'll fit your need for completely dependable, low-cost, versatile static control, write—and see why Nikita looks worried. *CONTROL, Dept. I-46, Butler, Pa. U. S. A.*

Reliability begins with CONTROL

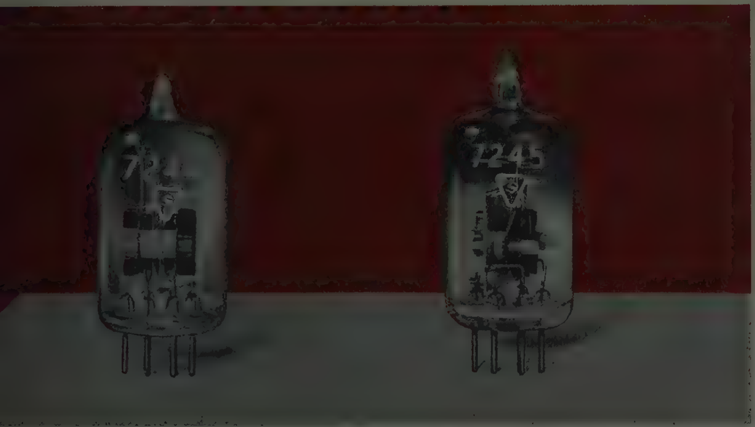
A DIVISION OF MAGNETICS, INC.

Expurgated translation: 'Heavens-to-Betsy!

Electron Tube News
-from SYLVANIA

Pioneering new concepts—Everywhere in electronics

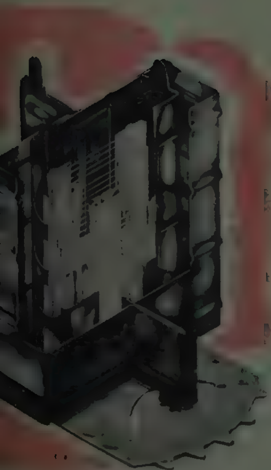
N BASIC TUBE DESIGN...


Double triode, type 7244, and single triode, type 7245

tacked mount in glass bulb offers practical answers o industry's current needs

Sylvania's stacked mount
tructure is now available to de-
ign engineers because of a new
lass envelope design that facili-
ates mass production of the
ubes. Complete electrical, me-
hanical and environmental tests
how that the new tube is capable
f meeting the highest require-
ents of today's operational
quipment. Its unique stacked
onstruction offers an inherent
uggedness and reliability for superior vacuum tube performance. Actual test data comparing the stacked structure with conventional structures indicates as much as a 2 to 1 improvement in vibrational output at 6 times the G level.

The new stacked tube has already excited tremendous military interest. Eventually an entire line will be available for military and industrial applications.


▲ Cutaway view of the Framelok design

Widespread interest in Sylvania's exclusive Framelok design fosters new type development

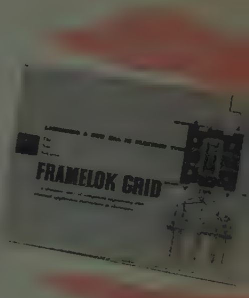
Accelerated development of new Framelok tube types is underway at Sylvania as a result of fast-growing acceptance of the revolutionary design shown for the first time at the 1958 IRE Convention.

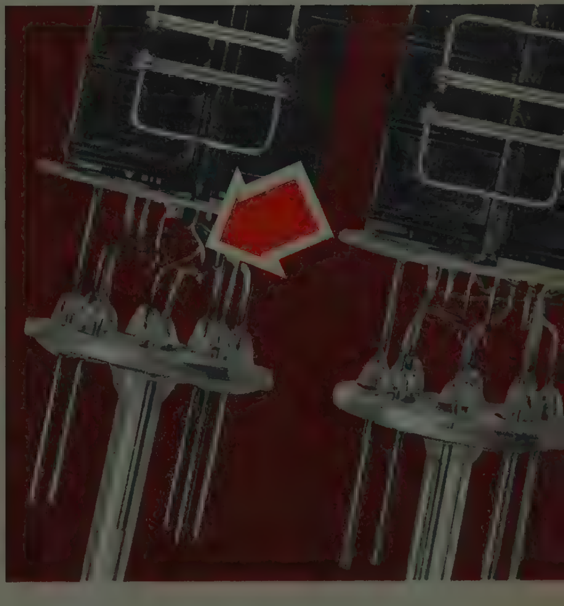
Design engineers are already analyzing new circuit requirements in terms of the Framelok design. New application possibilities ranging from television to audio are developing rapidly.

Behind this widespread acceptance are these basic reasons why designers prefer the Framelok design over conventional types:

• Greater uniformity of electrical characteristics in tube after tube • Greater stability of electrical characteristics during tube life • Less change in electrical characteristics due to element temperatures at high dissipation levels • Better control of cutoff • Lower knee voltage—more uniform control of knee • Less chance for shorts, microphonism and noise • Better plate-to-screen current ratio • Higher screen grid dissipation • Less arcing.

Send for your free copy of Sylvania's new Framelok Grid Booklet, including a grid sample, for full information on the electrical and mechanical characteristics of the Framelok design





Entertainment receiving tubes are subjected to military-type inspection procedures

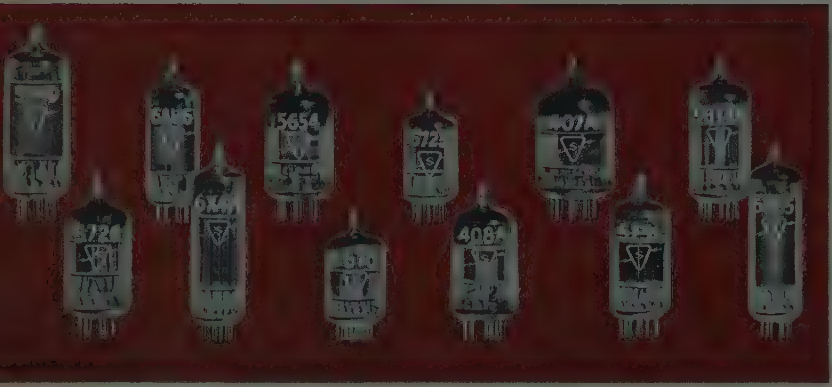
These two mounts may look alike to the untrained eye . . . but trained inspection personnel can spot defects in one (left) that could cause future trouble. All Sylvania entertainment tube types must pass this visual mount inspection procedure based on that used for military types. As a result equipment manufacturers enjoy fewer line rejects, lower manufacturing costs.

SYLVANIA SETS THE
Gold Brand Standard

Gold Brand Subminiatures undergo 1,000-hour life tests

Life tests on subminiatures are increased to insure maximum reliability

Sylvania increases the life assurance on its premium subminiature tube line by increasing its life test program from 500 to 1,000 hours. The increase establishes additional positive proof of the high reliability and excellent performance of the subminiature tube line.



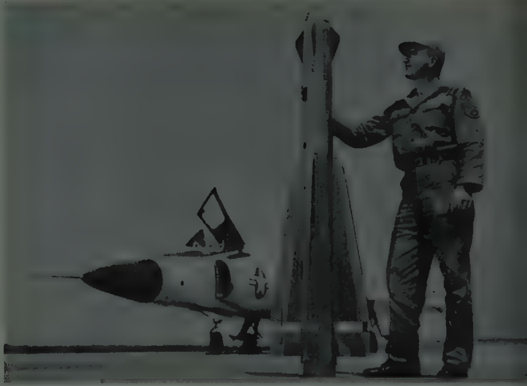
Gold Brand types meet rigid new specifications

Sylvania writes new Gold Brand Specs for commercial and industrial applications

To meet your needs for reliable tubes in commercial and industrial equipment, Sylvania has written new specifications which tailor military standards to commercial, and industrial requirements. Some of the typical controls specified for Gold Brand tubes include Multiple Life Tests ranging from 500 to 1,000 hours, Impact Shock Tests of up to 500 G, Fatigue Tests, Vibration Tests, Glass Strain Tests and Variable Control Tests.

The following are the 12 Gold Brand types on which full specifications are available:

Type	Description
407A	Medium-mu double triode (9-pin miniature)
408A	Sharp-cutoff pentode (7-pin miniature)
6AU6WA	Sharp-cutoff pentode (7-pin miniature)
6X4WA	Double diode (7-pin miniature)
5654	Sharp-cutoff pentode (7-pin miniature)
5670	Medium-mu double triode (9-pin miniature)
5725	Dual-control pentode (7-pin miniature)
5726	Double diode (7-pin miniature)
5749	Semi-remote cutoff pentode (7-pin miniature)
5751	High-mu double triode (9-pin miniature)
5814A	Medium-mu double triode (9-pin miniature)
6005	Beam Pentode (7-pin miniature)



Gold Brand types meet missile requirement

Gold Brand Premium Guided Missile types withstand severe durability tests

Every tube type in Sylvania's Gold Bran Guided Missile line meets environmental testing more severe than that required in man advanced military specs. Each type is subjected to severe vibrational fatigue tests a sweep frequencies from 30 cps to 3000 cps a 10 G's for 6 hours in several standard positions

All Gold Brand Sylvania subminiature tube undergo the White Noise Test. The tubes ar subjected to a white noise vibrational spectrum covering the frequency band of 100 t 5000 cps., the rms G-level is 2-3 G's per octav with peak G-level of 15 G's. The tubes ar tested for both rms and peak vibrational output and limits are established on each.

Type	Description
6946	Medium-Mu Triode
6947	Medium-Mu Double Triode
6948	High-Mu Double Triode
6788	Sharp cutoff audio-frequency pentod
6943	Sharp cutoff RF Pentode
6944	Semi-Remote cutoff RF Pentode
6945	Audio-Frequency Beam Pentode

Gold Brand subminiature Type 6814 meets rugged requirements of airborne computers

Type 6814 for missile computer

Prime example of a Gold Brand subminiature ideally suited for airborne computer use is type 6814. Fully proven in current operational equipments the tube features controlled sharp cutoff and zer bias plate current for good switching action. It exhibits exceptional freedom from development of cathode interface throughout life.

The 100% Production DC shorts test a well as a standard AC shorts test on type 681 minimizes the possibility of flicker shorts—assuring greater reliability in this tube's many applications, particularly in switching an triggering circuits. In addition, it withstand a minimum 1000-hour life test.

You can get the complete engineering stor on Sylvania's Gold Brand Lines in the new 33-page Gold Brand booklet.

N NEW TUBE YPES . . .

ive new types are added to the eceiving tube line

ype 12DV8—Designed for 12-volt auto adios, this 9-pin miniature double-diode, pace charge grid tetrode can be used as combined detector, AVC rectifier and ransistor driver. The tetrode section has he advantage of low R_p for better transistor matching.

ype 12EG6—This tube is designed primarily for use in 12-volt auto radios as an RF amplifier. It is a 7-pin miniature dual ontrol Heptode with a unipotential cathode. AVC voltage can be applied to two ontrol grids reducing back biasing of the AVC line with large RF signals.

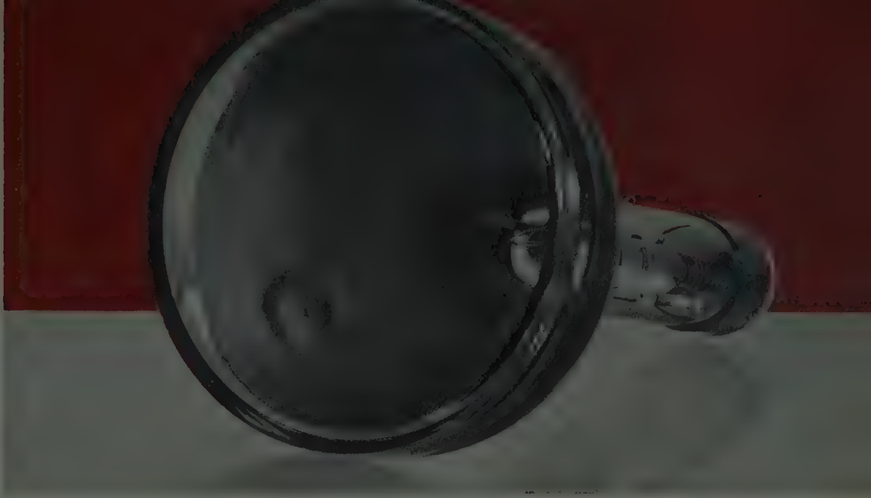
ype 12DZ6—This miniature pentode has remote cutoff to give a Gm of 50 umhos at a bias of 10 to 12 volts for improved AGC characteristics in hybrid radio receivers. The plate resistance of 15,000 ohms, coupled with a Gm of 3600 umhos, insures high performance in weak signal areas.

Type 12DU7—This 9-pin miniature double diode-tetrode can be used as a transistor driver in addition to functioning as a detector and AVC rectifier in hybrid auto receivers. In this multipurpose, low-cost tube, power output distortion is controlled to a maximum of 5%.

Type 12DV7—A double diode-triode for use in 12-volt hybrid auto radios. With a 12-volt plate supply the triode features a plate current of 750 ua, a mu of 15 and a Gm of 1000 umhos. The diodes feature a separate cathode connection for maximum flexibility in detector and AVC circuits.

New receiving tube types

12DV8
12DV7
12DU7
12EG6
2DZ6



New five-inch experimental evaporated phosphor CRT

IN NEW TRANSPARENT PHOSPHOR TUBES . . .

Experimental five-inch evaporated phosphor CRTs offered for applications research and development

Steady progress is being made in the development of evaporated (transparent) phosphor cathode-ray tubes at Sylvania. Now 5-inch and other small tubes are being produced and are available for experimental purposes.

High industry interest in evaporated (transparent) phosphor tubes is centered around the major benefits the tubes offer over conventional CRT s. Among the more important characteristics are:

- **Higher resolution**—Transparent screens are capable of higher resolution than conventional settled screens because the phosphor crystals are smaller by many orders of magnitude. Video displays with sharper definition are possible.
- **Improved contrast** in high ambient light conditions—Transparent phosphors permit outside light to pass through the "screen" cutting reflection to a minimum. This characteristic is highly important where scopes must operate in high ambient light.
- **Minimum Screen Noise**—Because evaporated phosphor crystals are much smaller than those in conventional coatings, screen noise, the interplay of light reflections on the crystal faces, is reduced. The result is sharpest possible definition.
- **More Uniform Light Output**—The phosphor coating on evaporated screen CRT s is some 10 times as thin as standard coatings. This smooth screen coating contributes to far greater uniformity in light output.
- **Less Screen Burn**—Transparent phosphor tubes offer better resistance to screen burning because the crystals are closer to the glass faceplate. This allows better heat dissipation and cooler operation.

Since all of these advantages are not available in a single evaporated phosphor tube design, it is necessary to specify which characteristics are most important for the intended application. Send full information on your particular application when you request experimental samples. Write to Sylvania direct or call your Sylvania representative.

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SYLVANIA ELECTRIC PRODUCTS INC.
1100 Main St.
Buffalo 9, N.Y.

In Industrial Television . . .

Special CRT is specifically designed for industrial TV monitor use

Now, higher fidelity in industrial television is possible with new cathode-ray tube, type 8FP4. It gives added definition and resolution to industrial television performance.

Type 8FP4 is an 8″ rectangular all-glass, magnetic focusing tube with an ion trap and 90° magnetic deflection.

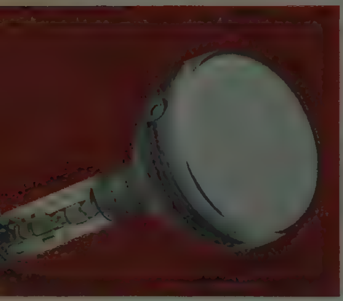
New test picture tube speeds receiver production line testing

A new 8″ 110° test picture tube, type 8YP4, is specifically designed for television receiver and picture tube testing. Its small size, light weight and convenient shape make it the ideal production line test tube.

The 8YP4 is equipped with a conventional base and a convenient adaptor for conversion to a rigid pin base. It has built-in automatic electrostatic self-focusing making external focus connections or adjustments unnecessary. It employs a 6.3 volt, 600 ma heater that will also operate in 450 ma series heater strings.

New ITV monit

In Industrial and Military C-R Tubes



New CRT type 5ADP2

New high-precision scope tubes, types 5ADP, 5ABP, and 5AQP, were developed for photography, radar and specialized uses

Sylvania again expands its line of special-purpose industrial and military cathode-ray tubes with a series of high-precision types designed for specialized uses. These tubes incorporate a high-precision electron gun made to ultra-fine tolerances. Sharp clean scope presentations result for high-precision photography.

The new tubes, types 5ADP, 5ABP, and 5AQP, are available in screen phosphors ranging from P1 to P11.

In Television Picture Tubes . . .

Sylvania combines the advantages of 110° deflection and 450 ma heater in three new picture tubes

Sylvania, trend setter in electron-tube design, has developed new 110° picture tubes incorporating the 450 ma 6.3 volt heater. The new tubes, types 17CTP4, 21DHP4 and 24AQP4, combine the space savings of 110° tubes with the power and cost advantages of 450 ma heaters. The low power heater not only reduces heat with total set power savings of approximately 18 watts but permits use of a lower wattage, less expensive series resistor The end result is a line of picture tubes that meet the need of new portable and console TV receiver designs.

Type 24AQP4 with
450 ma heater

SYLVANIA

Sylvania Electric Products Inc.
1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.
University Tower Bldg., Montreal

LIGHTING · TELEVISION · RADIO · ELECTRONICS · PHOTOGRAPHY · ATOMIC ENERGY · CHEMISTRY-METALLURG

Please send the following information on the items checked below:

ENGINEERING DATA SHEETS

Receiving Tubes
- ☐ 7244
- ☐ 7245
- ☐ 12DV8
- ☐ 12EG6
- ☐ 12DZ6
- ☐ 12DU7
- ☐ 12DV7

Cathode-Ray Tubes
- ☐ 5ABP
- ☐ 5AQP
- ☐ 5ADP
- ☐ 8FP4
- ☐ 8YP4
- ☐ 17CTP4
- ☐ 21DHP4
- ☐ 24AQP4

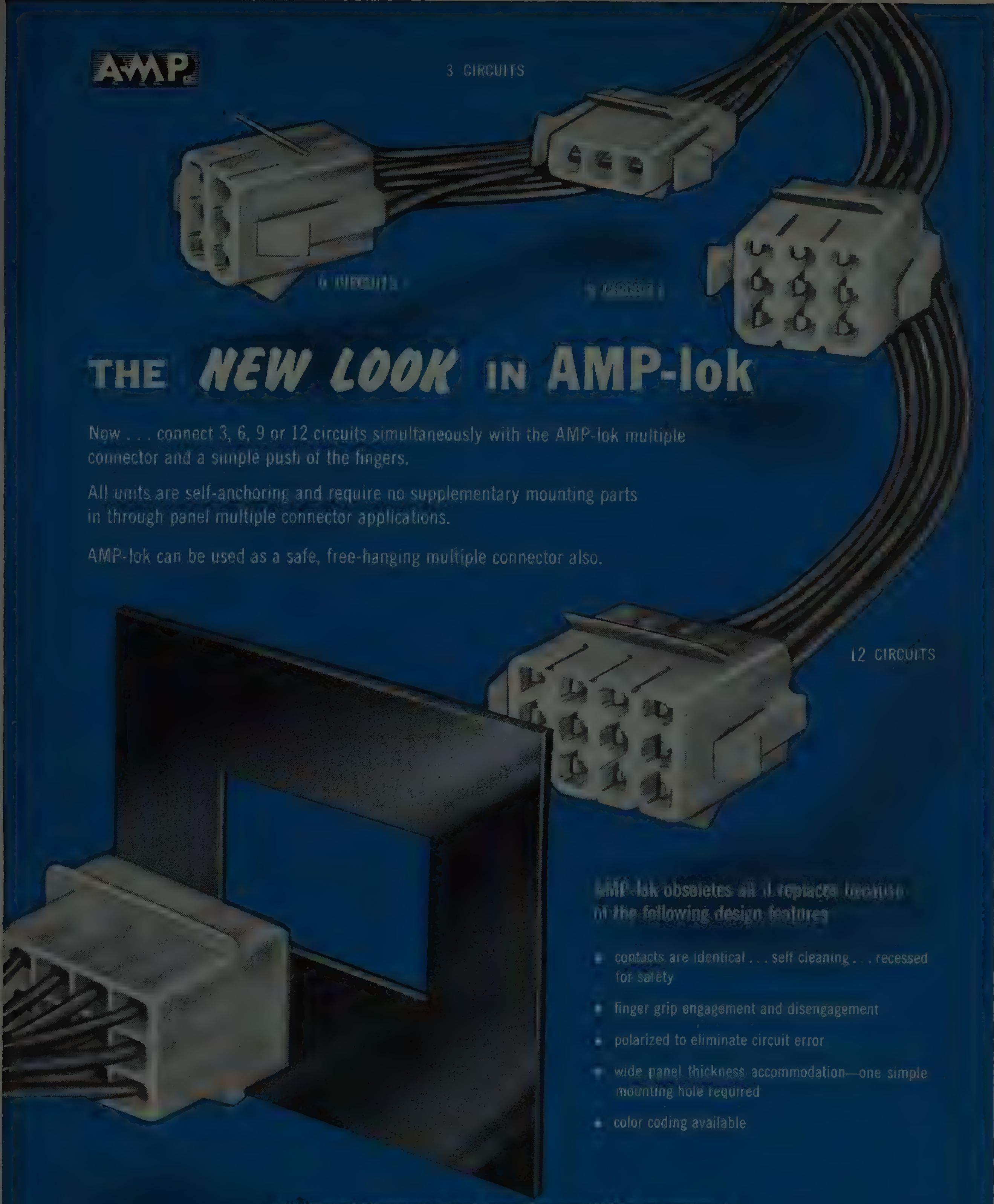
- ☐ Sylvania Framelok Grid Booklet
- ☐ Sylvania Gold Brand Booklet
- ☐ Additional explanation, and application requirement form for Sylvania transparent phosphor CRT s

Name________________________________

Address________________________________

Company________________________________

Use this handy business reply card to request additional information on these important new Sylvania developments



THE *NEW LOOK* IN AMP-lok

Now . . . connect 3, 6, 9 or 12 circuits simultaneously with the AMP-lok multiple connector and a simple push of the fingers.

All units are self-anchoring and require no supplementary mounting parts in through panel multiple connector applications.

AMP-lok can be used as a safe, free-hanging multiple connector also.

AMP-lok obsoletes all it replaces because of the following design features

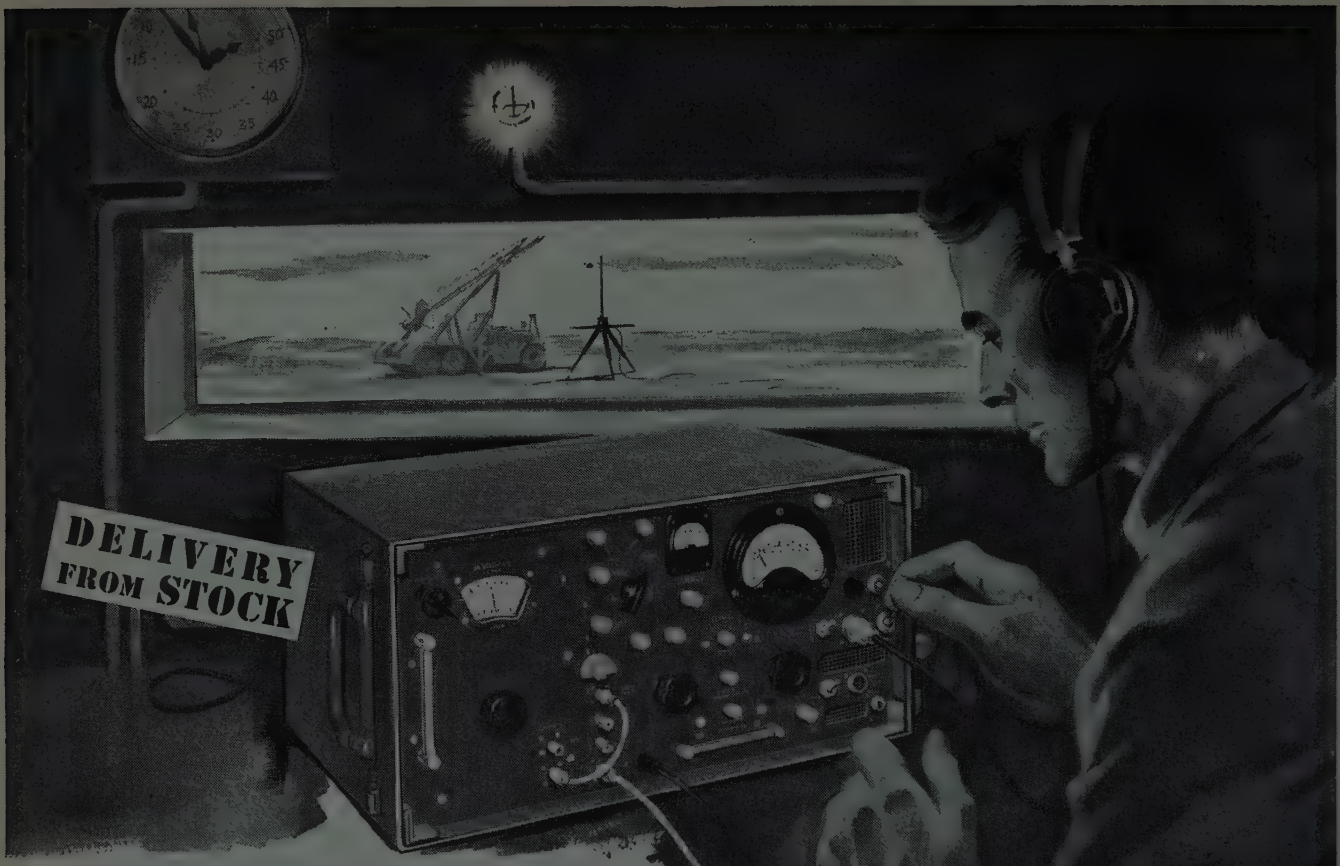
- contacts are identical . . . self cleaning . . . recessed for safety
- finger grip engagement and disengagement
- polarized to eliminate circuit error
- wide panel thickness accommodation—one simple mounting hole required
- color coding available

Additional literature and samples available on request.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through wholly-owned subsidiaries in: Canada • England • France • Holland • Japan



FLEXIBILITY IN THE FIELD...

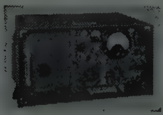
just one of the many useful features of

EMPIRE'S NOISE & FIELD INTENSITY METER

MODEL NF-105

Model NF-105 remotely located from its antenna, for personnel safety.

- Measures 150 kilocycles to 1000 megacycles accurately and quickly with only one meter.
- Approval status: MIL-I-6181B, Class 1 MIL-I-6181C, Category A; MIL-I-26600 (USAF)
- Direct substitution measurements by means of broad-band impulse calibrator, without charts, assure repeatability.
- Self-calibrating, for reliability and speed of operation.
- True peak indication by direct meter reading or aural slideback.
- Four interchangeable plug-in tuning units, for extreme flexibility.
- Economical . . . avoids duplication.
- Safeguards personnel . . . ALL antennas can be remotely located from the instrument without affecting performance.
- Compact, built-in regulated A and B power supply, for stability.
- Minimum of maintenance required, proven by years of field experience.



Only the Model NF-105 is so simple to operate that one technician can take readings over the entire frequency range in less time than required by three engineers manning any other three separate instruments.

Send for our Catalog No. N-357

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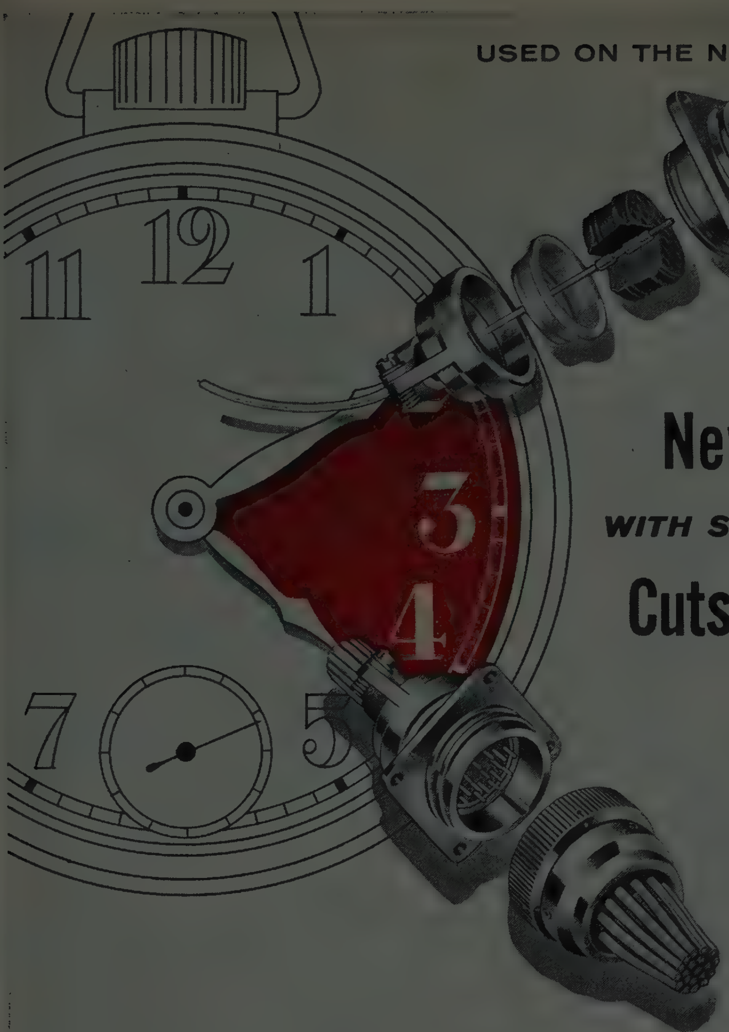
AMSTERDAM, NEW YORK
VICTOR 2-8400

MANUFACTURERS OF:
FIELD INTENSITY METERS • DISTORTION ANALYZERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS • CRYSTAL MIXERS

USED ON THE NEW BOEING B-52 JET BOMBER



New MS Miniature Plug

WITH SOLDERLESS SNAP-IN CONTACTS

Cuts Wiring Assembly Time as much as 80%

CANNON KM SERIES
FIRST TO MEET MIL-C-25955
(USAF) SPECIFICATIONS

THE PROBLEM—To design a miniature environmental-resistant connector, suitable for use on present and future aircraft, missiles and equipment, in accordance with military requirements. Dependability with simplicity to facilitate assembly, installation and field service were vitally important.

THE SOLUTION—Crimp-type solderless contacts, with wire insulation support, are used in the new KM. They can be easily snapped into place, or removed as necessary. Individual contacts can be serviced one at a time, without removing others. A specially designed moisture-sealing grommet replaces potting. Closed entry, machined socket contacts are probe-proof. All materials are of finest obtainable quality. Shells and related parts are of aluminum alloy, cadmium plated. Contacts are plated with gold over a heavy silver undercoat.

These features combine to provide a plug of optimum reliability that can be assembled and installed with utmost speed and be easily serviced in the field.

The new KM mates with the Cannon KO Plug Series, and is available in a wide variety of shell sizes, styles and insert layouts. Hermetically sealed receptacles also available. *For complete information write for Catalog KM-1.*

Come to Cannon for all plug needs—27,000 kinds to choose from. If we do not have what you want we'll make it for you. The largest facilities in the world for plug research, development and manufacturing are at your service. Write us today about your problem. Refer to Dept. 374

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AUDIO-VIDEO AIRCRAFT SWITCHING POWER MISSILE UNIT PLUG-IN INDUSTRIAL

MADE BY THE WORLD'S LARGEST MANUFACTURER OF PLUGS AND CONNECTORS FOR ALL INDUSTRIES

NEWS New Products

Audio Engineering Society Announces Convention Program

A disclosure of recent revisions and improvements in the Westrex stereo disk recording head which made the whole stereo disk development in this country possible will be among the important papers read at the 10th Annual Convention of the Audio Engineering Society, to be held daily September 29 through October 3 at the Hotel New Yorker, it was announced today by D. J. Plunkett, Chairman of the Papers Committee.

A new feature of the Convention will be the first exhibition of professional, nonconsumer audio equipment to be sponsored by the Audio Engineering Society. The exhibition will be held in open booths on the mezzanine floor of the Hotel New Yorker. The first such show organized strictly by and for audio engineers, it will be "silent" with no audible demonstrations of "high fidelity" permitted. Exhibit hours are noon to 7:30 P.M. daily.

As in prior years, concurrently with the AES Convention, the Institute of High Fidelity Manufacturers will hold its annual consumer New York High Fidelity Show, at the nearby New York Trade Show Building.

About 60 engineering papers will be presented during the Convention, according to Plunkett, necessitating two evening sessions in addition to those scheduled for each morning and afternoon. Among papers of wide interest to be read is a full engineering description of the RCA stereophonic tape cartridge which is already, in advance of its commercial release, heavily influencing the tape industry.

Others are: a method for checking the axes of operation of stereo recording heads, presented by H. G. Redlich of Teldec, developers of the leading European stereo recorder; a description of the Ortofon stereo recorder, by H. Arentzen, of Ortofon Industries, Denmark; a paper on the new Ampex Master Equilization method which improves the subjective signal to noise ratio of magnetic tape; a method for determining the absolute recording sensitivity of magnetic tape, presented by E. D. Daniel and I. Levine of the National Bureau of Standards; a description of a new device, a magnetic groove disk, for broadcast station use; an evening session of several papers on electronic music, led by Professor Vladimir Ussachevsky of Columbia University.

The Annual Banquet, with presentation of fellowships and awards by the Society, will be held at 6:00 P.M. on Thursday night, October 2, in the Grand Ballroom of the Hotel New Yorker.

The complete list of subject titles of the Convention sessions follows:

Monday, September 29
9:30 a.m.—Transistor Application Problems
1:30 p.m.—Psychoacoustics of Stereo
7:30 p.m.—Music and Electronics
Tuesday, September 30
9:30 a.m.—Disk Recording and Reproduction
1:30 p.m.—Disk Recording and Reproduction
7:30 p.m.—The Stereo Listener's Needs
Wednesday, October 1
9:30 a.m.—Magnetic Recording and Reproduction
1:30 p.m.—Magnetic Recording and Reproduction
Thursday, October 2
9:00 a.m.—Annual Business Meeting
9:30 a.m.—Magnetic Recording
1:30 p.m.—Standards and Measurement
6:00 p.m.—Cocktail Party and Annual Banquet
Friday, October 3
9:30 a.m.—Audio Applications
1:30 p.m.—Loudspeaker Design and Applications

Volt-Ohm-Ammeter

Keithley Instruments, Inc., 12415 Euclid Ave., Cleveland 6, Ohio, has designed the Model 610 Electrometer which makes virtually all dc measurements required in laboratory and production tests. The single unit includes: (1) an ultrahigh impedance voltmeter, with a range of 200 microvolts to 30 kv, (2) a direct-reading ammeter from 3 amperes to 10^{-14} ampere. (3) a linear-scale ohmmeter, measuring 0.2 ohm to 10^{+14} ohms, with internal resistance standard, and (4) a convenient dc preamplifier with precise gains to 1000.

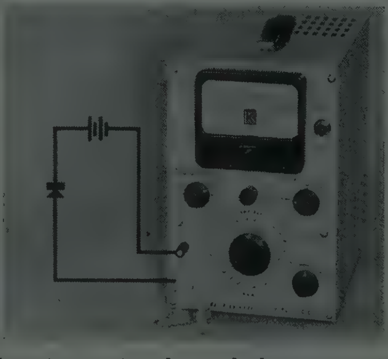
Other features include a selectable input impedance from one ohm to greater than 10^{+14} ohms; 10-volt and 1-milliampere outputs to drive oscilloscopes and recorders; and accessory voltage divider probes and test shield.

Typical uses cover practically all dc laboratory tests, including measuring inverse current of a semi-conductor, voltages in piezo-electric crystals and vacuum tube electrodes; currents in photo cells and ion chambers; and very high resistances.

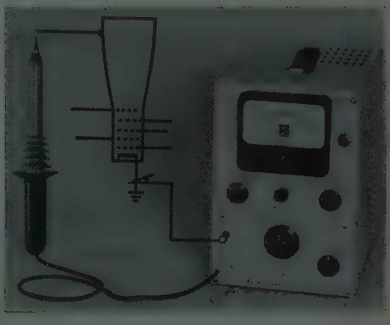
Details are available from the firm.

(Continued on page 114A)

Resistor check, using Keithley 610 and Test Shield. Both guarded and unguarded connections are available. Accuracy is within 3 per cent of full scale up to 3 x 10^8 ohms and within 5 per cent beyond.



Measuring semi-conductor back current with Model 610. Serving as a direct-reading ammeter, the Keithley 610 reads currents from 3 amperes to 10^{-14} ampere full scale. Accuracy is 3 per cent of full scale from 3 amperes to 10^{-8} ampere; 4 per cent of full scale from 3 x 10^{-9} to 10^{-14} ampere.



Typical voltage measurement using Keithley Model 610. The instrument has full scale ranges of 0.01, 0.03, 0.10, 0.30, 1.0, 3.0, 10, 30 and 100 volts. Accuracy is within 2 per cent of full scale on all ranges. Input impedance is selectable from one ohm to greater than 10^{14} ohms.

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- aids in the design of conservatively rated circuits for greater reliability.

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IRE People

A. S. Brown

The degree of Doctor of Engineering has been conferred upon **Archibald S. Brown** (A'14–SM'47–F'56–L), of Stanford Research Institute by Montana State College at Bozeman, Montana, in recognition of outstanding achievements and contributions in the fields of radio and electronics and support to that institution in starting electronic research activities. He also has the B.S. and E.E. degrees.

Mr. Brown, widely known in the radio and electronic engineering profession, was one time Executive Engineer of the old Federal Telegraph Company of California, at Palo Alto when Dr. Leonard F. Fuller was Vice-President of that company. Previously, he performed engineering work in Naval Radio Communications throughout the Pacific Coast, Alaska, Hawaii, Guam, the Philippine Islands, and China. For six years prior to the war he was Chief Engineer of Air Navigation, Research and Development with the Signal Corps and Air Corps at Wright Field.

A Navy Reserve officer for many years, he was ordered to active duty early in 1941 as Electronic Officer in the New York area. He served throughout the war and is now Captain, USNR, retired. In 1946 he went to the Air Force as a radio engineer, becoming a Chief Staff Engineer, under General Tom C. Rives, and later Technical Director, Operations, Weapons Component Division, Wright Air Development Center, under General Gordon A. Blake,

Dr. Brown has been at Stanford Research Institute as a Special Assistant to the Director of Engineering Research since 1951. He has been an active member of the Administrative Committees of the Professional Groups on Engineering Management and Military Electronics, and is a member of AFCEA, WCEMA, and the Naval Institute.

❖

Mervin J. Kelly (M'25–F'38), President of Bell Telephone Laboratories, will be the 1959 recipient of the John Fritz Medal for "his achievements in electronics, leadership of a great industrial research laboratory, and contributions to the defense of the country through science and technology." The medal is sponsored jointly by the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. Presented not more than once in any year for "scientific or industrial achievement" in any field of pure or applied science, it was established in 1902 as a memorial to the engineer and steel maker whose name it bears.

Dr. Kelly joined the research division of the Engineering Department of Western Electric, predecessor of Bell Laboratories, in 1918. Assignments as director of vacuum tube development and development director of transmission instruments and electronics preceded his appointment in 1936 as director of research. He became executive vice-president in 1944 and president of the Laboratories in 1951.

In recognition of his direction of military research and development programs during World War II, he received the Presidential Certificate of Merit. Since the war he has held several public service assignments in Washington, particularly with the Atomic Energy Commission, the Department of Commerce, and the Department of Defense. He is a member-at-large of the Defense Science Board. Among his many honors are the Air Force Exceptional Service Award and the 1953 Trophy of the Air Force Association, awarded "for distinguished service to air power in the field of science."

Dr. Kelly is active in the field of education. He is a Life Member of the Massachusetts Institute of Technology Corporation and a member of its Executive Committee, a Trustee of Stevens Institute of Technology, and serves on advisory committees at M.I.T., Princeton, New York University, Case Institute of Technology, Columbia University, and the N. Y. City Board of Education.

He is also a trustee of the Alfred P. Sloan Foundation and of the corporation of Atoms for Peace Awards.

A recent achievement in the interests of the engineering profession has been Dr. Kelly's chairmanship at the industry campaign to fund the new $10,000,000 United Engineering Center, the national headquarters for engineering societies whose membership totals over a quarter of a million engineers.

A graduate of the Missouri School of Mines and Metallurgy, Dr. Kelly received the Ph.D. degree from the University of Chicago in 1918. He has been awarded seven honorary doctorates by American and European universities.

He is a member of the National Academy of Sciences and the American Philosophical Society, a Foreign Member of the Swedish Royal Academy of Sciences, and is associated with many other scientific and professional societies.

❖

(Continued on page 36A)

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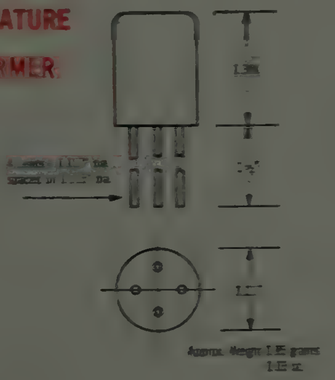

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Dr. George L. Haller, Chairman, General Electric Co., Syracuse, N.Y.

26 Transactions, *5, *6, *8, & *9, and *Vol. ANE-1, Nos. 1, 2, 3 and 4; Vol. 2, No. 1-4; Vol. 3, No. 1-2-3-4; Vol. 4, No. 1, 2, 3, 4; Vol. 5, No. 1.

Antennas and Propagation

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Technical advances in antennas and wave propagation theory and the utilization of techniques or products of this field.

Dr. R. L. Mattingly, Bell Telephone Labs., Whippany, N.J.

22 Transactions, *4, *Vol. AP-1, Nos. 1, 2; *Vol. AP-2, Nos. 1-4; AP-3, No. 1-3; AP-4, No. 1-2-3; AP-5-1-4; AP-6-1, 2, 3.

Audio

Annual publications fee: $2.

Technology of communication at audio frequencies and of the audio portion of radio frequency systems, including acoustic terminations, recording and reproduction.

Mr. F. H. Slaymaker, Chairman, Stromberg-Carlson, Rochester, N.Y.

41 Transactions, *5, *7, *10. *Vol. AU-1, Nos. 1-6; *Vol. AU-2, Nos. 1-6; Vol. AU-3, Nos. 1-6; Vol. AU-4, No. 1-2-3-4-5-6; Vol. AU-5, No. 1-5; AU-6, No. 1, 2.

Automatic Control

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The theory and application of automatic control techniques including feedback control systems.

Mr. John E. Ward, Chairman, Servomechanisms Lab., MIT, Cambridge 39, Mass.

5 Transactions, PGAC-1-2-3-4-5.

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The design and manufacture of broadcast and television receivers and components and activities related thereto.

Mr. Harland A. Bass, Chairman, Avco Mfg. Corp., Arlington, Cincinnati, Ohio.

20 Transactions, *1, *2, *3, *5, *6, *7, 8; BTR-1, No 1-4. BTR-2, No. 1-2-3. BTR-3, No. 1-2. BTR-4, No. 1-2, 3.

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20 Transactions, *1, *2. *Vol. CT-1, Nos. 1-4; CT-2, No. 1-4; CT-3, Nos. 1-4; CT-4, No. 1-4; CT-5, No. 1, 2.

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Capt. E. N. Dingley, Jr., Chairman, Electronic Communications Inc., St. Petersburg 10, Fla.

11 Transactions, *Vol. CS-1, No. 1; *Vol. CS-2, No. 1-2; CS-3, No. 1; CS-4, No. 1-2-3; CS-5, No. 1, 2, 3; CS-6, No. 1.

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2 Transactions, Vol. E-1, No. 1, 2.

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Dr. Willis H. Ware, Chairman, Rand Corp., Santa Monica, Calif.

26 Transactions, *Vol. EC-2, No. 2-4; *Vol. EC-3, No. 1-4; EC-4, No. EC-7, No. 1, 2.

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Dr. G. A. Rosselot, Chairman, Bendix Aviation Corp., Detroit 35, Mich.

12 Transactions, *1, *2-3. EM-3, No. 1-2-3; EM-4, No. 1-2, 3, 4; EM-5, No. 1, 2.

Engineering Writing and Speech

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Mr. W. R. Thurston, Chairman, General Radio Co., Cambridge 38, Mass.

6 Transactions, *PGIE-1-2-3-4-5-6.

Information Theory

Annual publications fee: $3.

Information theory and its application in radio circuitry and systems.

Dr. Thos. P. Cheatham, Jr., Chairman, Melpar, Inc., 43 Leon St., Boston, Mass.

13 Transactions, *2, *3, 4. IT-1, No. 1-2-3; IT-2, No. 1-4; IT-3, No. 1, 2, 3, 4; IT-4, No. 1, 2.

Instrumentation

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Mr. L. C. Smith, Chairman, Hycon Eastern, Inc., 75 Cambridge Parkway, Cambridge 42, Mass.

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Dr. Urner Liddel, Chairman, Natl. Insts. of Health, Bethesda, Md.

11 Transactions, 1-11.

Microwave Theory and Techniques

Annual publications fee: $3.

Microwave theory, microwave circuitry and techniques, microwave measurements and the generation and amplification of microwaves.

Dr. T. S. Saad, Chairman, Sage Labs., Inc., Wellesley 81, Mass.

22 Transactions, *Vol. MTT-1, No. 2; *Vol. MTT-2, No. 1-3; MTT-3, No. 1-6; MTT-4, No. 1-2-3-4; MTT-5, No. 1-2-3, 4; MTT-6, No. 1, 2, 3.

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Annual publications fee: $2.

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Mr. E. A. Speakman, Chairman, RCA Defense Elec. Products, Camden 2, N.J.

2 Transactions, MIL-1, No. 1, 2.

Nuclear Science

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Application of electronic techniques and devices to the nuclear field.

Dr. A. B. Van Rennes, Chairman, Bendix Aviation Corp., Detroit 35, Mich.

10 Transactions, NS-1, No. 1; NS-2, No. 1; NS-3, No. 1-4; NS-4, No. 1, 2; NS-5, No. 1, 2.

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New advances and materials applications for the improvement of production techniques, including automation techniques.

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Mr. Harold R. Schwenk, Chairman, Sperry Gyroscope Co., Great Neck, L.I., N.Y.

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Techniques of determining and controlling the quality of electronic parts and equipment during their manufacture.

Mr. P. K. McElroy, Chairman General Radio Co., West Concord, Mass.

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10 Transactions, TRC-1, No. 1-2-3; TRC-2, No. 1; TRC-3, No. 1-2, 3; TRC-4, No. 1.

Ultrasonics Engineering

Annual publications fee: $2.

Ultrasonic measurements and communications, including underwater sound, ultrasonic delay lines, and various chemical and industrial ultrasonic devices.

Dr. John E. May, Jr., Bell Telephone Labs., Whippany, N.J.

6 Transactions, PGUE, 1, 2-3-4, 5, 6.

Vehicular Communications

Annual publications fee: $2.

Communications problems in the field of land and mobile radio services, such as public safety, public utilities, railroads, commercial and transportation, etc.

Mr. A. A. MacDonald, Chairman, Motorola, Inc., 4545 W. Augusta Blvd., Chicago 51, Ill.

11 Transactions, *1, *2, *3, *4, 5, 6, 7, 8, 9, 10, 11.

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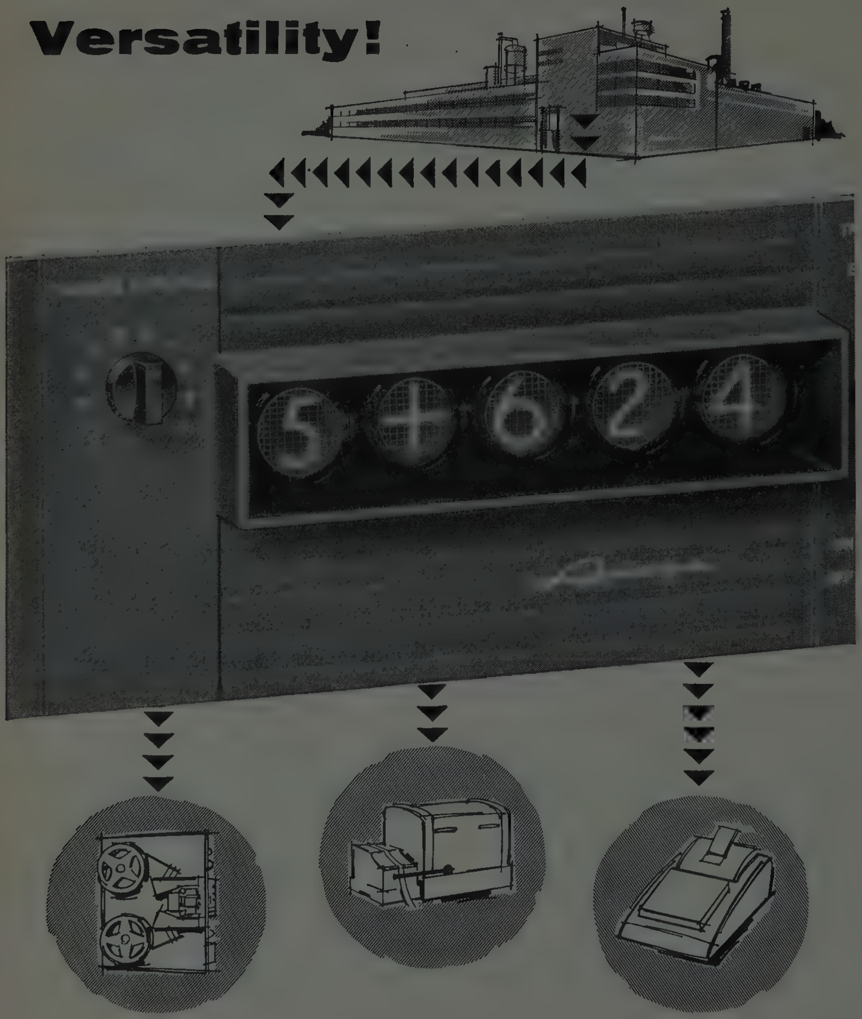

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IRE People

(Continued from page 42A)

Albert O. Behnke (M'46–SM'52), North American Air Defense Command, Air Technical Intelligence Specialist, recently received the Decoration for Exceptional Civilian Service from General Earle E. Partridge, NORAD Commander-in-Chief for outstanding performance of duty during June, 1954 through May, 1956.

A graduate of Iowa University with the Bachelor of Science degree, Mr. Behnke has taken graduate work at Harvard University, Massachusetts Institute of Technology, and The Ohio State University.

❖

Andre G. Clavier (M'30–F'39), Vice President of ITT Laboratories, Nutley, N. J., has been elected President of the American Section of the Societe des Ingenieurs Civils de France. The object of the section is to foster friendly relations between engineers of American and French nationalities and to keep its members informed of French scientific and engineering developments.

A member of the ITT system since 1929, Mr. Clavier was a key figure in the development of microwave radio, directing ITT's successful demonstration of microwave transmission across the English Channel in 1931. He also was among the first to investigate the over-the-horizon microwave technique, now employed in the revolutionary ITT telephone-TV link between Florida and Cuba.

Henri Busignies (M'42–SM'43–F'45), President of ITT Laboratories, is a member of the Society's Board of Directors.

❖

Gerald J. Adams (A'42–M'48–SM'50), **Lindsay Russell** (A'53), and Oliver H. Straus have formed a new company, the Adams-Russell Co., Inc., at 292 Main St., Cambridge 42, Mass.

Mr. Adams has been a project manager and a group head at Hycon Eastern, Inc. of Cambridge, Mass., for the last three years. For the preceding eight years, he was senior engineer at Alford Consulting Engineers of Boston. Prior to that he was an assistant group leader at CBS in the Engineering Research and Development Division. He is a member of Eta Kappa Nu.

Mr. Russell was formerly a project engineer at Hycon Eastern, Inc., and was also a project engineer at Alford Consulting Engineers from 1951 to 1956. He is a member of Sigma Xi, Tau Beta Pi and Eta Kappa Nu.

The new company is engaged in electronics manufacturing, research and development, and consulting. It began its operations on June 2, 1958.

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(Continued on page 48A)

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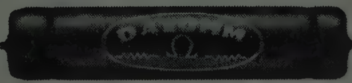

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At the same time they provide a wide margin in meeting power, precision and reliability requirements. They are designed especially for sub-miniature applications.

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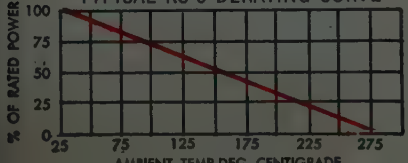
- Operating temperature range: −65° C. to 275° C.
- Precision tolerance range: 0.05%, 0.1%, 0.25%, 0.5%, 1% and 3%.
- Rated at 1, 2, 3, 5, 7, and 10 watts.
- Resistance range from 0.3 ohm to 175,000 ohms. (depending on size)
- Surpasses requirements of MIL-R-26C.
- Temperature coefficient: 0.00002/degree C.
- Complete welded construction from terminal to terminal.
- Silicone sealed, providing maximum protection from abrasion, moisture, salt spray and other environmental conditions, and assures high dielectric strength.

TYPICAL RS-5 DERATING CURVE



TWO NEW SUPER-MINIATURE SIZES for TRANSISTORIZED CIRCUITRY

RS-1A
3/32 X 13/32 inches,
1 watt,
.05 ohm to 30K ohms.

RS-1B
3/32 X 17/32 inches,
1 watt,
1 ohm to 10K ohms.

COMPLETE RANGE OF WIRE WOUND POWER RESISTORS

RS-2A
3/16 X 13/16 inches,
2 watts,
.5 ohm to 28K ohms.

RS-2B
3/16 X 9/16 inches,
3 watts,
.5 ohm to 20K ohms.

RS-2
1/4 X 5/8 inches,
3 watts,
.05 ohm to 30K ohms.

RS-5
5/16 X 7/8 inches,
5 watts,
.1 ohm to 60K ohms.

RS-7
5/16 X 1-7/32 inches,
7 watts,
.1 ohm to 90K ohms.

RS-10
3/8 X 1-25/32 inches,
10 watts,
.3 ohm to 175K ohms.

Request Bulletin R-23 for complete specifications

JUST ASK US...

DALOHM line includes a complete selection of miniature precision power resistors (wire wound and deposited carbon), precision wire wound miniature trimmer potentiometers, and collet fitting knobs. Write for free catalog.

If none of DALOHM standard line meets your need, our engineering department is ready to help solve your problem in the realm of development, engineering, design and production. Just outline your specific situation.

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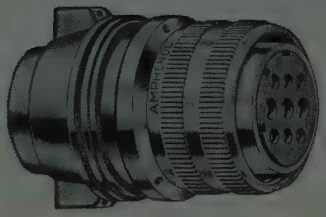
NEW AMPHENOL



ACTUAL SIZE

STUB E

smallest, lightest MS "E" connector

Stub E connectors meet or surpass the environmental resistance requirements of MIL-C-5015C. Stub E connectors are the *stubbiest* MS "E" designs available—AMPHENOL took advantage of every space-saving trick in the engineer's book while at the same time meeting all dimensional requirements of MIL-C-5015C.

Stub E connectors have a fully unitized rear sealing grommet assembly in which the grommet, compression nut and ring are a single unit, making assembly and disassembly quick and easy. Solder pockets of the silver-plated contacts are pre-filled for easier, less expensive soldering.

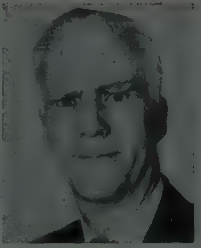
Shell styles 3100, 3101, 3102 and 3106, sizes 8S through 36 and 51 insert arrangements are available.

AMPHENOL

AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois

(Continued from page 46A)

An independent physics, patent, and research consulting service was recently opened on July 1 by **George E. Ziegler** (SM'46), who resigned as director of research of the Zonolite Company, Chicago, on that date.



G. E. Ziegler

Offices will be at 3020 Grant St., Evanston, Ill. Consultation in the fields of general and advanced physics, electro-mechanics, optics, electronics, and the construction industries will be provided.

Dr. Ziegler will remain associated with Zonolite, manufacturer of vermiculite products, as a research consultant. He is a former director of the Midwest Research Institute, Kansas City, Mo. He holds a Ph.D. degree in physics from the University of Chicago, and is a registered U. S. Patent Office agent.

Consulting services will include court service as a patent expert witness, preparation of advanced physics patent applications, and application of physics technology in sales presentations.

Other services include evaluation of company patent and research positions as an investment analysis tool, and consultation on research management.

Dr. Ziegler's professional experience includes posts as assistant professor of physics, Illinois Institute of Technology; and chairman of physics research, Armour Research Foundation, Chicago.

He is a member of numerous professional societies, including the American Physical Society, American Chemical Society, Optical Society of America, American Management Association, and Sigma Xi.

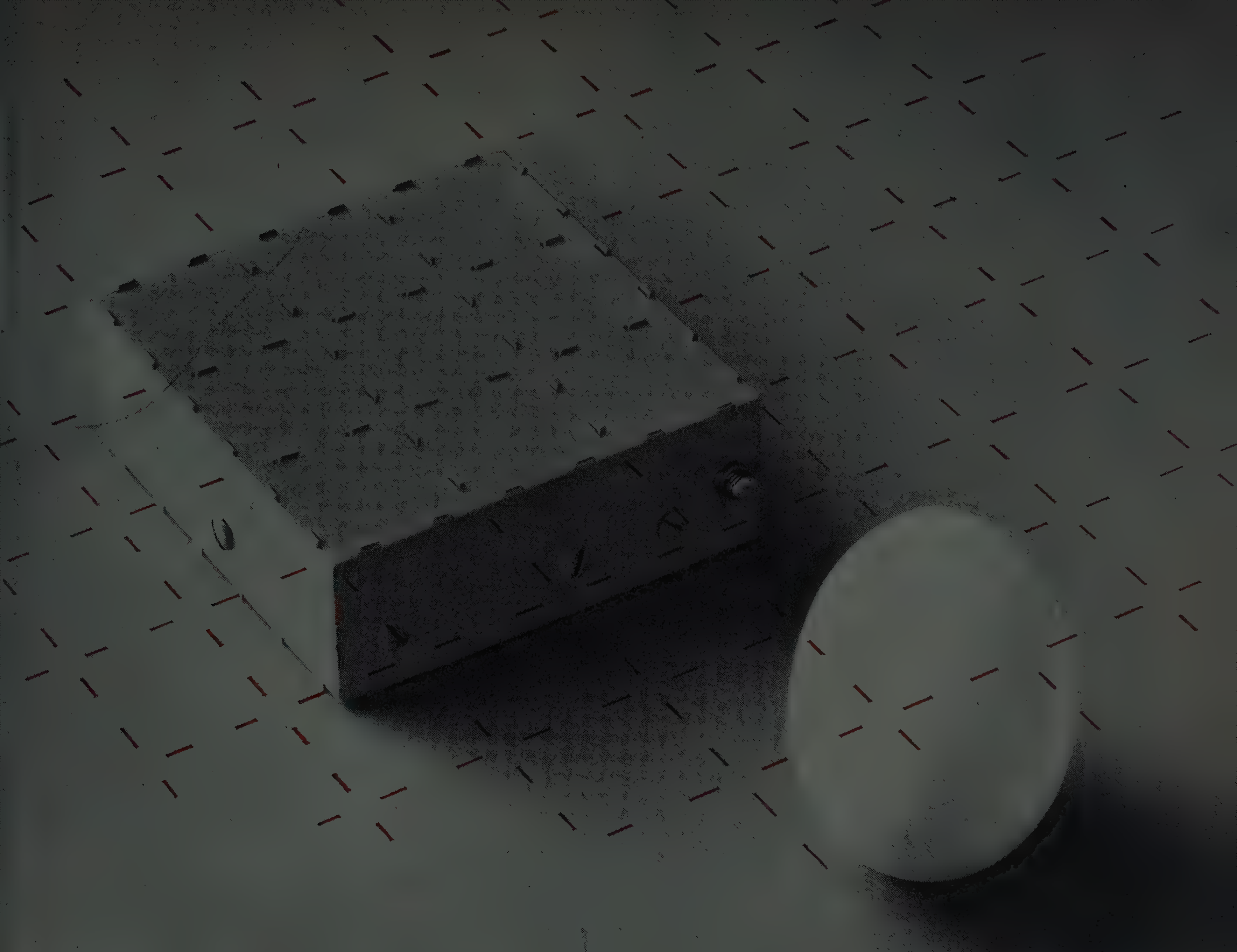
❖

Ernst Weber (M'41–SM'43–F'51), was recently inaugurated as the sixth president of the Polytechnic Institute of Brooklyn. He had been affiliated with the Institute for 27 years and was formerly its vice-president for research and acting president.

Dr. Weber's activities in the IRE are too numerous to mention here. He is an IRE Director, a member of the Professional Groups, Executive and Standards Committees, and an IRE Representative to the ASA Sectional Committee (C16) on Radio, ASA Electrical Standards Board, ASA Standards Council, U. S. National Committee of the International Electrotechnical Commission, and the U. S. National Committee of URSI.

❖

(Continued on page 50A)



Better shape factor over wider frequency range

Daven's new EGG CRATE LC filters...

Center frequency: covers the range from 0.4 MC to 60.0 MC depending upon specific requirements. Center frequency stability: ±1.0 KC per MC from -55°C to +105°C. Shape factor: BW_{60}/BW_6 *to 2.1. Shape factors can be modified for optimum time delay.*

In addition to these outstanding specifications, Daven's new LC filters offer a unique type of construction which makes them the most rugged filters ever built. Small cells are welded together to form the partitioned shield compartment...making this the first filter with truly continuous mechanical and electrical bond...providing a high degree of inter-circuit shielding.

Daven's new LC filters are ideal for shaping the pass band of AM/FM or FM/FM data link receivers, double or single side band receivers and generators, direction finding receivers, communication and telemetering receivers, and spectrum analyzers. So versatile, in fact, that applications are almost limitless. Write today for complete, newly-published technical data.

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By JOHN L. BOWER, Univ. of Cal., L.A.; and PETER M. SCHULTHEISS, Yale University.
Stresses the importance of finding a systematic approach to design, with emphasis on basic understanding of feedback phenomena and feedback systems design rather than specific components. *1958. 510 pages. $13.00.*

2. SWITCHING CIRCUITS AND LOGICAL DESIGN
By SAMUEL H. CALDWELL, Massachusetts Institute of Technology.
Treats methods of handling problems of circuit synthesis, and presents principles of switching circuit design necessary for a knowledge of the complex applications of switching theory. *1958. 686 pages. Illus. $14.00.*

3. AN INTRODUCTION TO COMBINATIONAL ANALYSIS
By JOHN RIORDAN, Bell Telephone Laboratories, Inc.
The only current book concerned with finding the *number of ways there are* of doing a well-defined operation. Includes numerous worked-out problems to illustrate the text and extend its meaning. One of the Wiley Publications in Statistics, Walter A. Shewhart and S. S. Wilks, Editors. *1958. 244 pages. Illus. $8.50.*

4. CIRCUIT ANALYSIS OF TRANSMISSION LINES
By JOHN L. STEWART, University of Southern California.
Covers: the steady state case, matching devices, design of resonators and transmission cavities, and the voltage standing-wave ratio. *1958. 186 pages. Illus. $5.50.*

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10. NOTES ON ANALOG-DIGITAL CONVERSION TECHNIQUES
Prepared by Staff Members of the M.I.T. Servomechanisms Laboratory; edited by ALFRED K. SUSSKIND, M.I.T.
Includes: the theory of sampling, quantizing, and coding; analysis and evaluation of basic coding and decoding methods for electrical and mechanical analog quantities; etc. A Technology Press Book, M.I.T. *1958. 410 pages. $10.00.*

11. CONFERENCE ON EXTREMELY HIGH TEMPERATURES
Sponsored by Electronics Research Directorate, Air Force Cambridge Research Center: HEINZ FISCHER and LAWRENCE C. MANSUR, Editors.
A useful summary of the underlying basis for commercial or usable thermonuclear reactions, with emphasis on high temperatures as they relate to propulsion fields. *1958. 258 pages. Illus. $9.75.*

12. AUTOMATIC PROCESS CONTROL
By DONALD P. ECKMAN, Case Institute of Technology.
Treats the important principles of automatic control, emphasizing block diagrams and frequency techniques in process control. *1958. 368 pages. Illus. $9.00.*

13. ZONE MELTING
By WILLIAM G. PFANN, Bell Telephone Laboratories, Inc.
Defines the potentialities of crystallization methods as yet unexploited for controlling the purity and precise composition of metals. *1958. 236 pages. Illus. $7.50.*

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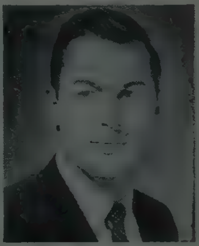
IRE People

(Continued from page 48A)

A new sales engineer, **Wayne H. Robinson** (S'55–A'56), has been named at Eitel-McCullough, Inc., San Bruno, Calif., manufacturer of Eimac electron-power tubes.


W. H. Robinson

Mr. Robinson joined Eimac in August, 1956 as administrative Assistant in marketing and in January, 1957 he was transferred to the production engineering department. Prior to Eimac he had experience in technical writing and instruction, equipment engineering and telephone exchange management.

He received his training at the Central Technical Insitute in Kansas City, Mo., and in military schools with the U. S. Army Signal Corps.

❖

Magnetic Metals Company of Camden, N. J., manufacturers of electromagnetic core products for the transformer industry, has announced the election of **Donald O. Schwennesen** (A'43–M'55), to the office of Vice-President. His duties will include both engineering and managerial responsibilities. Mr. Schwennesen, who joined Magnetic Metals Company in 1956, is an authority in the specialty and small transformer field. An electrical engineering graduate of the Illinois Institute of Technology in 1933, Mr. Schwennesen was formerly Vice-President in Charge of Sales and Engineering for Chicago Standard Transformer Corporation where he assisted the industry in defining and meeting critical World War II military specifications for small transformers.

❖

Fred A. Brooks, Jr. (S'55–M'56), has recently joined the staff of Dunlap and Associates, Inc., a research-consulting firm in Stamford, Conn. He was formerly associated with the Electric Boat Division of General Dynamics Corporation, Groton, Conn., as head of the Analog Computer Section.

Mr. Brooks is a graduate of Massachusetts Institute of Technology and the University of Connecticut, where he received the M.S. degree in electrical engineering. He is a member of the Executive Committee of the IRE Professional Group on Human Factors in Electronics.

❖

David Packard (S'34–A'41–SM'47–F'48), president of the Hewlett-Packard Company, Palo Alto, Calif., has been elected to the Board of Directors of Stanford Research Institute, Menlo Park, Calif. He will also serve on the Executive Committee of the Board.

Mr. Packard was named President of

(Continued on page 54A)

high reliability . . . extreme compactness . . .

IN THE

NEW SANBORN
850

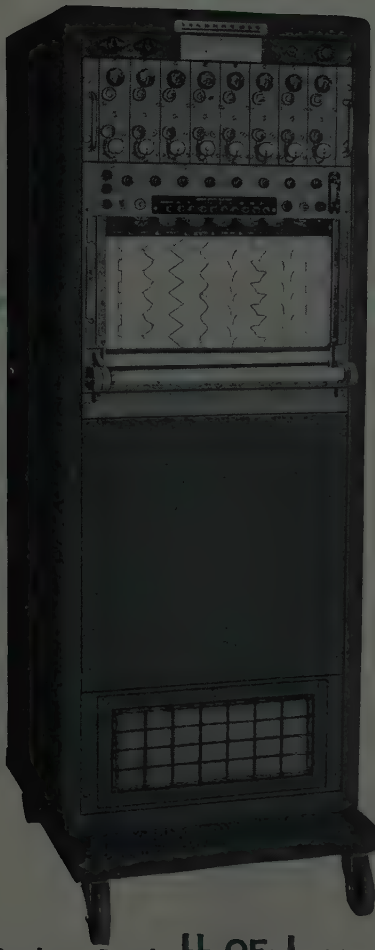
6- & 8-CHANNEL DIRECT WRITING SYSTEM

If you want a practical direct writing system for straightforward recording in the range from DC to 100 cps — such as computer readout, telemetry recording — look what the new Sanborn "850" offers in compactness, reliability and operating convenience. A complete 8-preamplifier module with power supply, plus an 8-channel flush-front recorder package containing power amplifiers and power supply at rear, occupy only 24½" of "850" panel space.

PERFORMANCE characteristics of an "850" include flat frequency response 0–70 cps, down 3 db at 100 cps (10 div. peak-to-peak amplitude) . . . thermal drift eliminated by current feedback power amplifiers . . . limiting at input to prevent amplifier saturation or cut off, so that damping is never lost . . . drift less than 0.2 div. for 20° to 40° C. changes, line voltage changes from 103 to 127 volts . . . gain stability better than 1% with 20° C. and 20 volt changes . . . linearity 0.2 div. over 50 divisions . . . clear, permanent, inkless recordings in true rectangular coordinates.

IN RELIABILITY, "850" features include fully transistorized power amplifiers and power supply . . . rugged galvanometers with low impedance, high current, enclosed coil assemblies and velocity feedback damping . . . JAN components wherever practical, such as MIL-T-27 hermetically sealed power transformers, MIL-approved electrolytics in power supplies, etc. . . . forced filtered air cooling for stable operation.

And in operating **CONVENIENCE,** an "850" system provides such advantages as nine electrically controlled chart speeds, selected by pushbuttons . . . a choice of interchangeable Preamplifiers (DC Coupling and Phase Sensitive Demodulator presently available, with others in development) . . . remote control of chart drive, speeds, timer and marker . . . monitoring connection points . . . a Recorder that loads from front and has built-in paper take-up and paper footage indicator.



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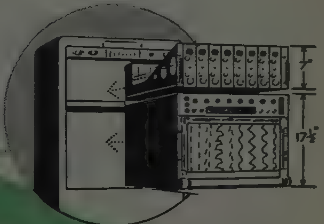

Ask your local Sanborn Industrial Sales-Engineering Representative for complete facts — or write the Industrial Division in Waltham.

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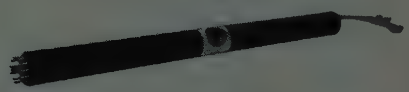
Rugged, compact, light in weight... all Hughes Microwave Tubes have withstood the most severe requirements of airborne radar systems and therefore can be applied in the most taxing of environmental problems.

KU BAND BACKWARD WAVE OSCILLATOR

The Hughes Type LOU-2 is a precision built oscillator which tunes over the frequency range of 12.4 to 18.0 kmc. Typical power output over band is 10 to 60 milliwatts. The tube is housed in a self-contained permanent magnetic focusing package so that a separate power supply for a focusing electromagnet is not required.

S-BAND TRAVELING WAVE AMPLIFIER

Periodically focused, the type MAS-1A has a peak power output of one kilowatt over a band of 2-4 kmc at duties up to 0.005. The tube has a gain of 30 to 33 db, giving an excess of one kilowatt over most of the band. When two tubes are operated in cascade, the one kilowatt output can be obtained with a drive on only one milliwatt.



S-BAND BACKWARD WAVE AMPLIFIER

The Hughes type PAS-2 is a narrow-band, voltage-tuned amplifier that is designed for use as an r-f preamplifier stage in contemporary radar communications and other microwave receivers. Features: frequency range 2.4-3.5 kmc, insertion noise figures on order of 4½ db, tube noise figures of less than 5 db, voltage-tuned, crystal protection, spurious input signal elimination, cold isolation greater than 80 db and image rejection.

For additional information please write: Hughes Products, Microwave Tubes, International Airport Station, Los Angeles 45, California. Or contact our local offices in Newark, Chicago and Los Angeles.

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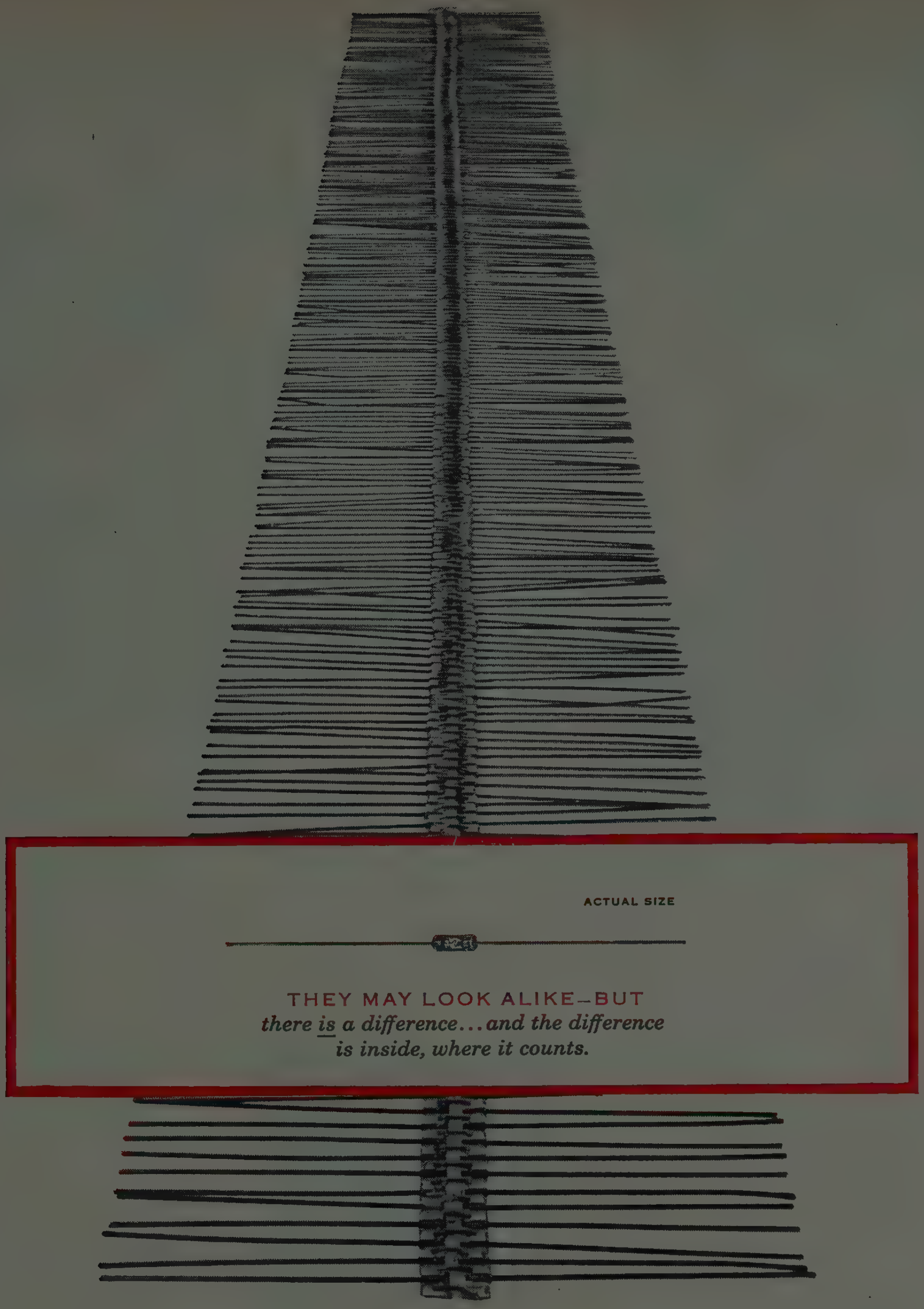

THEY MAY LOOK ALIKE—BUT
there is a difference... and the difference is inside, where it counts.

All Hughes diodes resemble each other—externally. Germanium point-contact or silicon junction, they are all glass-bodied* and tiny (maximum dimensions: 0.265 by 0.107 inch). But minute, meticulously controlled variations in the manufacturing process impart individual characteristics to the diodes, make them just right for specific applications. This gives you the opportunity of selecting from a line which includes literally hundreds of diode types.

So, when your circuitry requires varying combinations of such characteristics as... high back resistance... quick recovery... high conductance... or high temperature operation, *specify Hughes.* You will get a diode with mechanical and electrical stability built in. You will get a diode which was manufactured first of all for reliability.

*Nowhere else have glass packaging techniques been developed to a comparable extent, for the Hughes process has many unique aspects. They are difficult to duplicate, yet are instrumental to the manufacture of diode bodies which are completely impervious to contamination and moisture penetration.

For descriptive literature please write: **HUGHES PRODUCTS, SEMICONDUCTOR DIVISION**
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SEMICONDUCTORS

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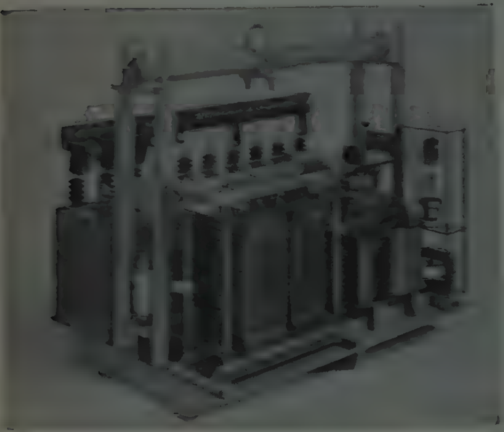
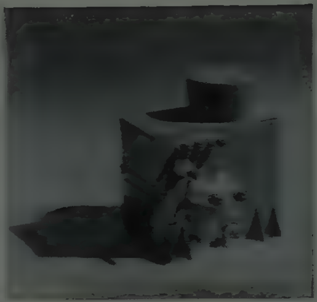


2003

235 KV peak at 10 μs pulse width
24 Megawatt peak pulse power
Approx. Size: 52" l. x 42" w. x 33" h.
Approx. Weight: 1500 lbs.
Klystron: Eimac Type X-632

2000

22 KV peak at [illegible] μs pulse width
440 KW peak pulse power
Approx. Size: 4½" l. x 3½" w. x 7" h.
Approx. Weight: 3.5 lbs.
Magnetron: Bomac Type BL213



2001

[illegible] KV peak at 1 μs pulse width
[illegible] KW peak pulse power
Approx. Size: [illegible] l. x [illegible] w. x 4 11/16" h.
Approx. Weight: 8 lbs. include
Magnetron: Raytheon Type QK400

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redwood city california
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IRE People

(Continued from page 50A)

the Board of Trustees of Stanford University earlier this year. In addition, he is a director of the American Management Association, Crocker-Anglo National Bank, Varian Associates, Granger Associates, Huggins Laboratories, and the Palo Alto Mutual Savings and Loan Association.

Before the formation of the Hewlett-Packard Company in 1939, he was associated with the General Electric Company. He holds several patents in the field of electronics and measurements.

He received the B.A. and E.E. degrees from Stanford University, and is a member of Phi Beta Kappa, Tau Beta Pi, and Sigma Xi.

⁂

Varian Associates, Palo Alto, Calif. has announced that **Kurt Schlesinger** (A'41–SM'51–F'54), has joined the electronics firm's newly organized research team directed by **Dr. Louis Malter** (A'37–SM'45–F'52).

Dr. Schlesinger was formerly associated with Motorola, Inc., Chicago, Ill., where he spent eleven years in television and electron tube research. His previous research and engineering experience included work with the Columbia Broadcasting System, Radio Corporation of America, Grammont in Paris, and Opta in Berlin.

A member of the British Television Society, London, Dr. Schlesinger holds over 200 U. S. Patents and has published more than 34 technical papers here and abroad.

⁂

Promotion of two General Electric managers has been announced by **H. A. Strickland, Jr.** (SM'56), general manager of the company's Industrial Electronics Division.

H. R. Oldfield, Jr. (SM'53), former general manager of the Computer Department, Phoenix, Ariz., has been appointed general manager of a new company component, the name of which has not yet been disclosed. He is succeeded by **C. C. Lasher** (A'47–SM'47), formerly manager of marketing of the Computer Department.

Mr. Oldfield, who now has successfully organized three General Electric components, has been assigned to Boston, Mass., to develop and head the new organization at the division level. Before becoming the first manager of the Computer Department, he had organized and managed both the Microwave Laboratory at Palo Alto, Calif., and the Advanced Electronics Center, Ithaca, N. Y. He joined the company in 1945 following his release from active duty with the army. During World War II, he received the Legion of Merit and the Army Commendation Ribbon for his achievements in the fields of ground and airborne radar fire control.

Earlier, he was an instructor at the Massachusetts Institute of Technology

(Continued on page 58A)

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CERAMIC-TO-METAL SEALS

Standard Items or Custom Designs

FROM ONE COMPLETELY INTEGRATED SOURCE

Whether specifications call for standard types of ceramic-metal bushings or specially designed assemblies for unusual applications, designers and electronics equipment manufacturers can rely on the uniform high quality and dependability of Alite ceramic-to-metal seals.

Vacuum-tight seals and bushings made of high alumina Alite are ideal for use in electronic applications where service conditions are extremely severe or critical. Alite has superior mechanical strength and thermal shock resistance. It maintains low-loss characteristics through a wide range of temperatures and frequencies. It resists corrosion, abrasion, and nuclear radiation. The extra-smooth, hard, high temperature glaze on Alite seals assures continuing high surface resistivity and dependable operation.

Another important reason for outstanding reliability of Alite components is our ability to perform and carefully supervise, in our own plant, every manufacturing step. From design to finished assembly—including formulating, forming, firing and testing—Alite is equipped to develop and produce high precision hermetic seals and bushings at one location. This permits an exceptionally high level of quality control, and results in what we sincerely believe to be the finest ceramic-to-metal seals available.

Our ceramics specialists are anxious to assist you on problems involving ceramic-to-metal seals. Tell us about your specific requirements today.

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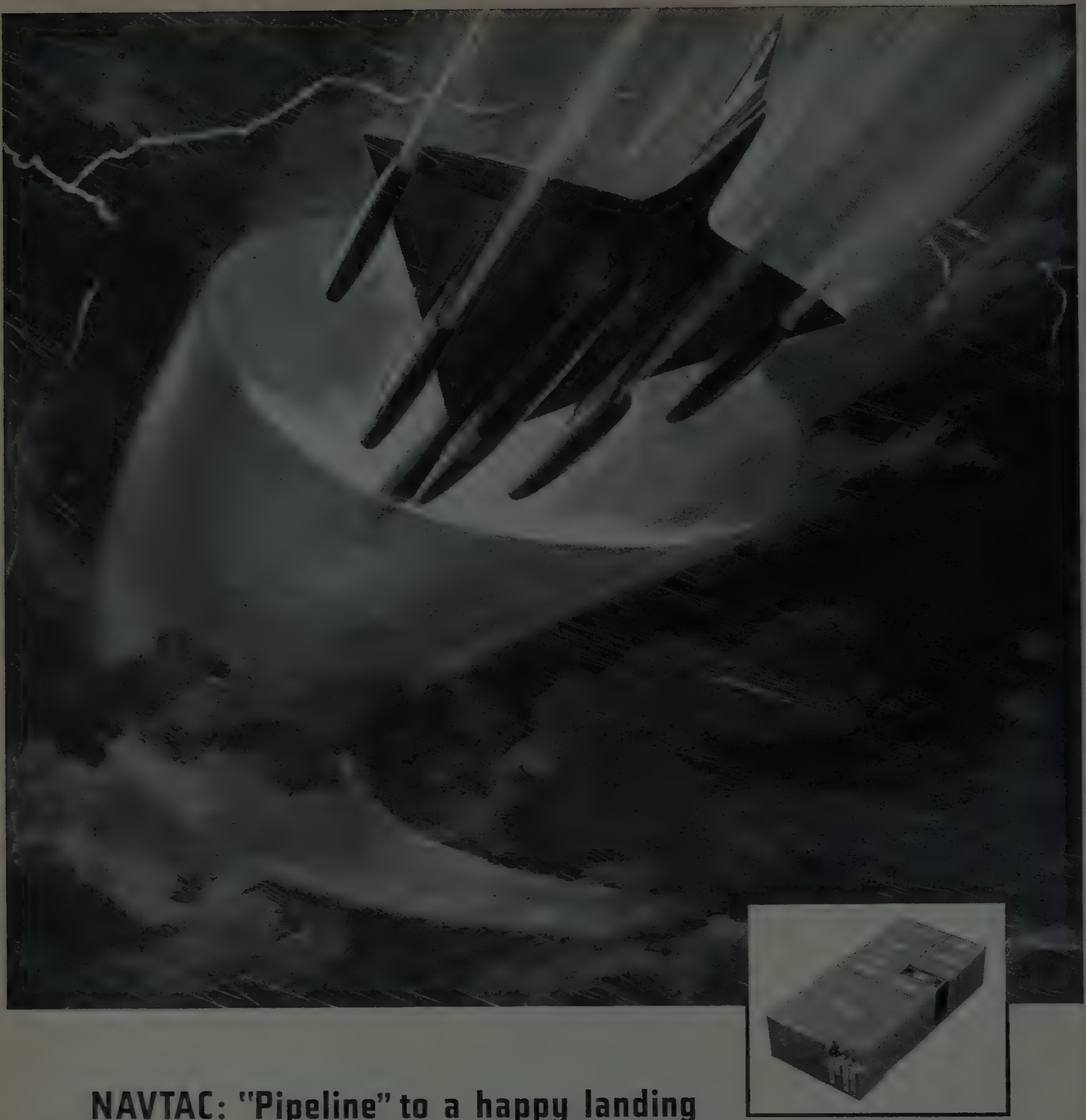

NAVTAC: "Pipeline" to a happy landing

The uniqueness of the new NAVTAC en route navigation and instrument landing system by Stromberg-Carlson is in its *combination* of functional modules.

The NAVTAC equipment is an assembly designed to provide high-performance aircraft with the TACAN navigational aid, plus marker beacon receiver, glide slope and runway localizer for instrument landing situations.

The entire system is packaged in a compact unit only 5" high, 10½" wide, 22" deep, and weighing only 47.5 lbs. Individual modules can be separated up to distances of several feet without any adverse effect on performance.

The equipment is designed to meet the rigorous environment of the high-performance aircraft of today and tomorrow. Its operating ambient temperature range is −60 to +125 degrees C. at altitudes up to 70,000 feet. Widespread use of semiconductors in the ILS receivers and TACAN circuitry means high reliability, small size and low power consumption.

Included in the design is the capability of performing complete preflight confidence tests with the use of a small auxiliary test set.

Complete technical details on the NAVTAC system are available on request.

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TWO WAYS . . .
- Highest-Grade INDIA RUBY Mica Films . . .
- TOTAL DEBUGGING . .

Guarantee Super Dependability*

the finest of materials...

superior engineering know-how . . . combine to build in El-Menco Dur-Mica Capacitors the highest reliability . . . to give long, ever-ready, powerful service in electronic equipment — from lightning-fast giant brains to tiny transistor receivers.

* unique features in El-Menco *Dur-Micas*

- Specially-selected, highest-grade India Ruby mica films . . . pre-tested to have highest insulation resistance . . . greatest dielectric strength . . . lowest dissipation factor. Specially developed dipped coating retains the superior properties of India Ruby mica.
- Debugging — the removal of early failures by subjecting mica capacitors to short life tests at elevated voltages and temperatures . . . THE SCORE . . . DM30, 10,000 MMF, "Debugged" El-Menco Dur-Mica Capacitors . . . subjected to 257,000 hours of life at 85°C with 100% of the rated DC voltage applied . . . turned in a record computed reliability performance — APPROX. 0.6% CUMULATIVE FAILURES OR ONLY 1 FAILURE PER 43 MILLION UNIT-HOURS.

El Menco "Dur-Micas" have *proved* their tremendous power and ability under accelerated conditions of 1½ times rated voltage at *ambient temperatures of 125°C and 150°C,* winning out over all others in longest life, most powerful performance, smallest size, greatest stability.

DM15, DM16, DM19, DM20, DM30, DM40, DM42, DM43 . . . perfect for extreme miniaturization; ideal for new miniatured designs and printed wiring circuits. New "hairpin" parallel leads insure easy applications in radio, television, guided missiles. El-Menco Dur-Micas meet all humidity, temperature and electronic requirements, including military specs.

Avoid Costly Breakdowns . . . with Two-Way Built-In Rugged Reliability.

DM15

DM20

63900±1%
El-Menco

DM42

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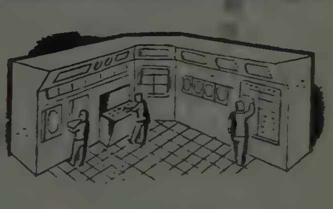

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We may surely point to a realistic salary structure but this is not the principal reason why we attract and retain outstanding people. A far more likely reason is that we are basically an engineering corporation. Because most of our top executives are engineers themselves they understand and appreciate technical problems, a fortunate situation which naturally induces an atmosphere most stimulating to creativity, harmony and professional progress.

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If you're a qualified *electronic components engineer* you'll find real challenge in either our electronic components engineering section or our electronics production design department. Here exceptionally stringent reliability standards continually push the state of the art in several areas and, in a responsible position, you'll enjoy this truly sophisticated work in reliability engineering.

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• ENGINEERS • ENGINEERS •

IRE People

(Continued from page 54A)

after obtaining both the B.S. and M.S. degrees there in aeronautical engineering. He was concerned during that period with the development of a device which was the forerunner of the series of computing gunsights developed by M.I.T.

He is a member of the Phoenix Chamber of Commerce, the Institute of Aeronautical Sciences, the Armed Forces Signal Association, and the Research Society of America, and an associate member of the American Ordnance Society, and the American Institute of Management.

Mr. Lasher has been with General Electric for 19 years. He joined the company in 1939 after his graduation from Pennsylvania State University with the E.E. degree, and has held engineering, manufacturing, and marketing managerial positions in the fields of communications, electronics, and computers. Before joining the Computer Department, he was manager of an instruments and industrial electronics study. In 1949 he received the Collier award for outstanding contributions to aeronautics while a member of the Radio Technical Commission for Aeronautics.

He is a member of Tau Beta Pi, Pi Mu Epsilon, and Eta Kappa Nu, and the Phoenix Chamber of Commerce.

❖

Election of five new vice-presidents of the consolidated ITT Laboratories, Nutley N. J., was announced recently by Edmond H. Leavey, president of the parent International Telephone and Telegraph Corporation.

The newly formed organization combines the research facilities of Farnsworth Electronics Company, Fort Wayne, Ind., and Kellogg Switchboard and Supply Company, Chicago, Ill., both ITT divisions, with Federal Telecommunication Laboratories, in Nutley, the former U. S. research division of ITT.

Among the new vice-presidents are four men who served as laboratory directors at FTL. The officers and their fields of responsibility are: **Louis A. De Rosa** (A'45–SM'51–F'52), Electronic Countermeasures; Sven H. Dodington, Avionics; **Armig G. Kandoian** (S'35–A'36–SM'44–F'51), Communication Systems; and **Arnold M. Levine** (A'44–M'55), Missile Systems.

The fifth man named to the post of vice-president is Dr. Charles D. W. Thornton, formerly director of Research and Development at Farnsworth, now responsible for Physical Sciences, Components, and Instrumentation.

In the expanded research and development organization, **Peter C. Sandretto** (A'30–M'40–SM'43–F'54) (Brig. Gen, USAF Res.) and **Andre G. Clavier** (M'30–F'39), will continue as vice-presidents and technical directors of government and commercial projects, respectively, positions they previously held at FTL. Dudley M. Day, formerly of FTL, will

(Continued on page 60A)

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TYPE 6528 RATINGS

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Max. plate dissipation per section	30 watts
Max. steady plate current per section	300 ma.
Max. plate voltage	400 volts
Max. heater cathode voltage	300 volts
Amplification factor*	9
Transconductance per section*	37,000 μmhos

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IRE People

(Continued from page 58A)

continue to serve as administrative vice-president, secretary, and treasurer, while **Henri Busignies** (M'42–SM'43–F'45) will direct the over-all activities of the Laboratories.

The electronic and communication research division will employ more than 3100 scientists, technicians, and supporting personnel, and will have a total floor space of more than 570,000 square feet. Major laboratory facilities will be located at Nutley and Belleville, N. J.; San Fernando and Palo Alto, Calif.; Fort Wayne, Ind.; and Chicago, Ill.

❖

R. Sackman

Robert Sackman (S'48–A'51), vice-president and general manager of Ampex Corporation, Redwood City, Calif., has been named to the board of directors of ORRADIO Industries, Inc., at Opelika, Ala., it was announced by J. Herbert Orr, president of the firm which manufactures magnetic recording tape.

Mr. Sackman, who has been with Ampex since 1953, has previously been manager of the company's Washington, D. C., district office, and vice-president and manager of the Instrumentation Division. He has had over twenty years of engineering and management experience in the electronics industry including the direction of a large research and development group in the Department of Defense, specializing in data processing systems, a magnetic recording devices, and communication equipment.

He received his education in electrical engineering at George Washington University, served in the U. S. Navy during World War II, and is a member of Sigma Tau, Armed Forces Communications and Electronics Association, Instrument Society of America, and the American Management Association.

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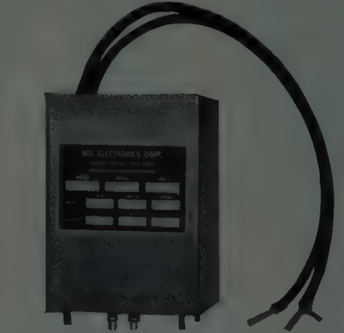

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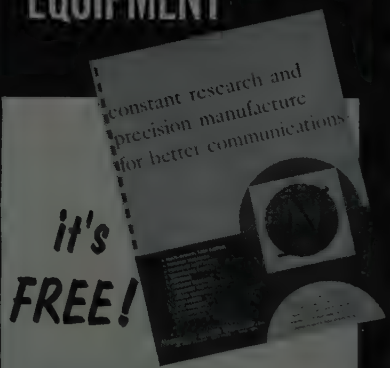

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Short Time Overload per Mil-R-10509B (4.6.5)	0 to ±0.15%	Less than ±0.10%	Less than ±0.10%
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Insulation Resistance per Mil-R-10509B (4.6.7)	Greater than 1,000,000 Megohms	Greater than 100,000 Megohms	Greater than 100,000 Megohms
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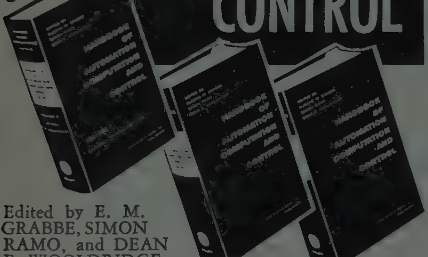

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(Continued on page 64A)

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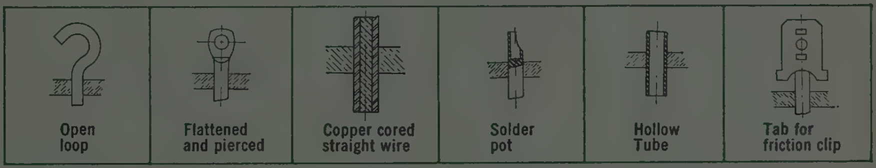
Open loop
Flattened and pierced
Copper cored straight wire
Solder pot
Hollow Tube
Tab for friction clip

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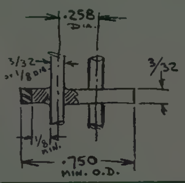
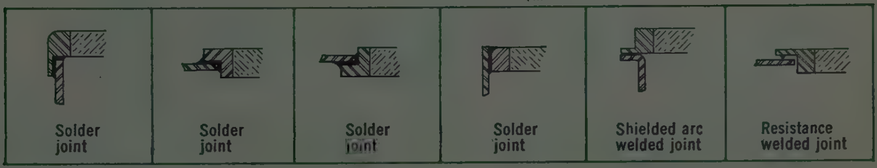

.258 DIA.
3/32 or 1/8 DIA.
3/32
1/8 MIN.
.750 MIN. O.D.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(Continued on page 66A)

Designed for Application

VIDEO DELAY LINES

Millen "Designed for Application" delay lines are available in lumped parameter designs to meet specific applications and as stock distributed parameter lines.

Distributed parameter delay line is available as bulk line, finished as flexible line with molded ends, or hermetically sealed in metal containers.

Characteristic Impedance:
1350 Ohms ± 20% or
550 Ohms ± 20%.

Time Delay Approximately 22 inches per microsecond for 1350 ohm line and 4.1 feet per microsecond for 550 ohm line. 0.1 to 5.6 microseconds in No. 34751 flexible assembly with molded ends. 0.1 to 0.4 microseconds in a container 1'' x 1'' x 5½'' and up to 16 microseconds in larger containers.

Rise Time: Function of delay. From approximately 12 millimicroseconds for 0.25 microseconds delay to approximately 0.4 microseconds for 16 microseconds delay.

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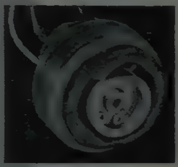
Size 11 Synchro



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RCA's "straight" electron-gun is designed to minimize deflection distortion—and eliminates the need for an ion-trap magnet. Inches shorter in length than 90°-deflection types having the same size faceplate, RCA 110°-deflection picture tubes with super-aluminizing produce bright, high-contrast pictures.

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from 15 cycles to 6 megacycles

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Input impedance 7.5 mmfds shunted by 11 megs

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Price $285

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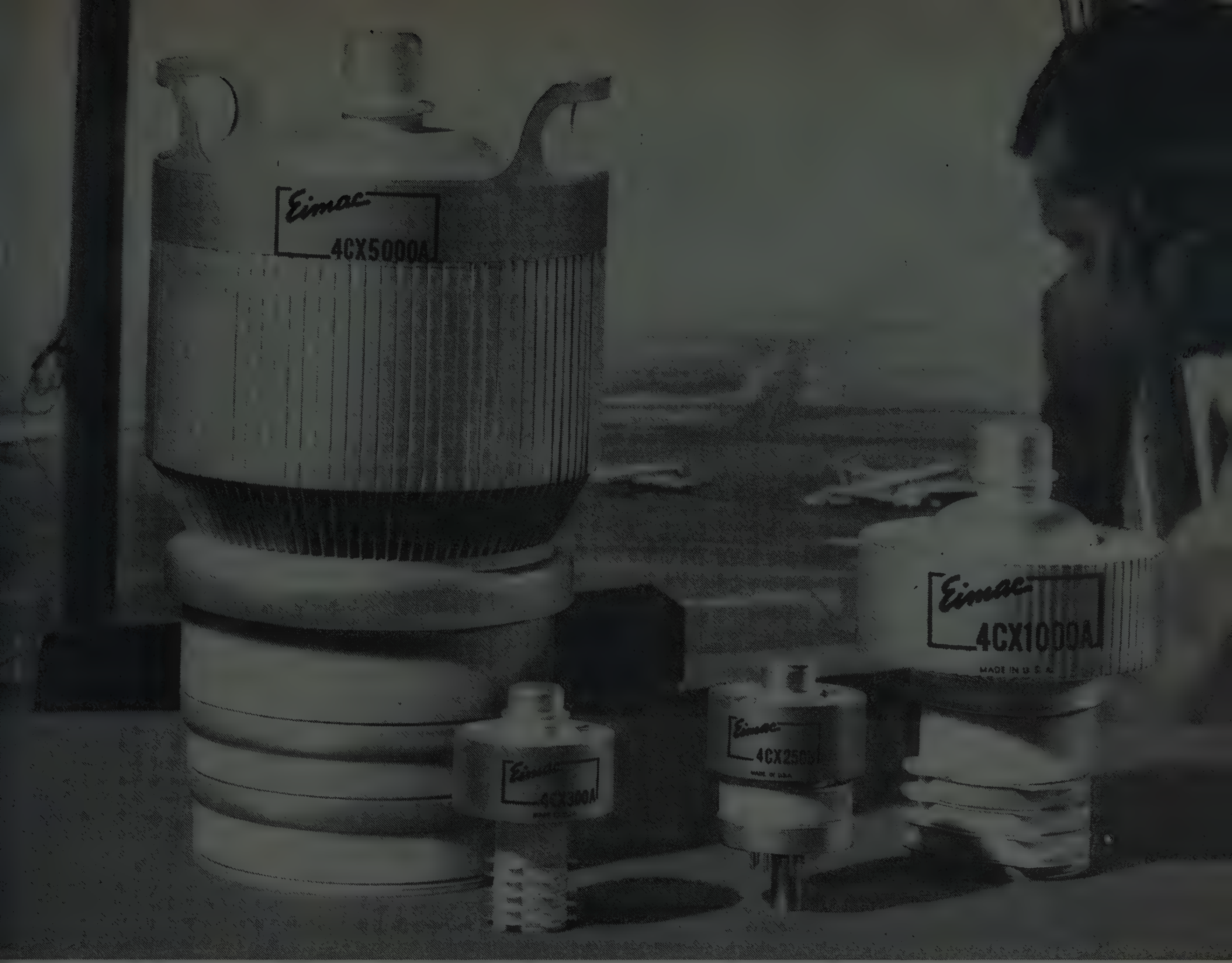

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CLASS AB_1 SSB OPERATION

	4CX250B	4CX300A	4CX1000A	4CX5000A
Plate voltage	2000 v	2500 v	3000 v	7500 v
Driving Power	0 w	0 w	0 w	0 w

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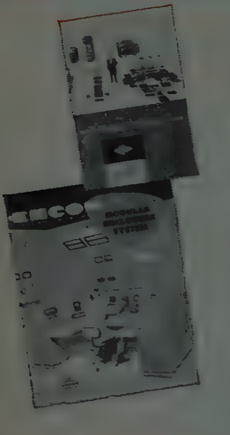

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(Continued on page 72A)

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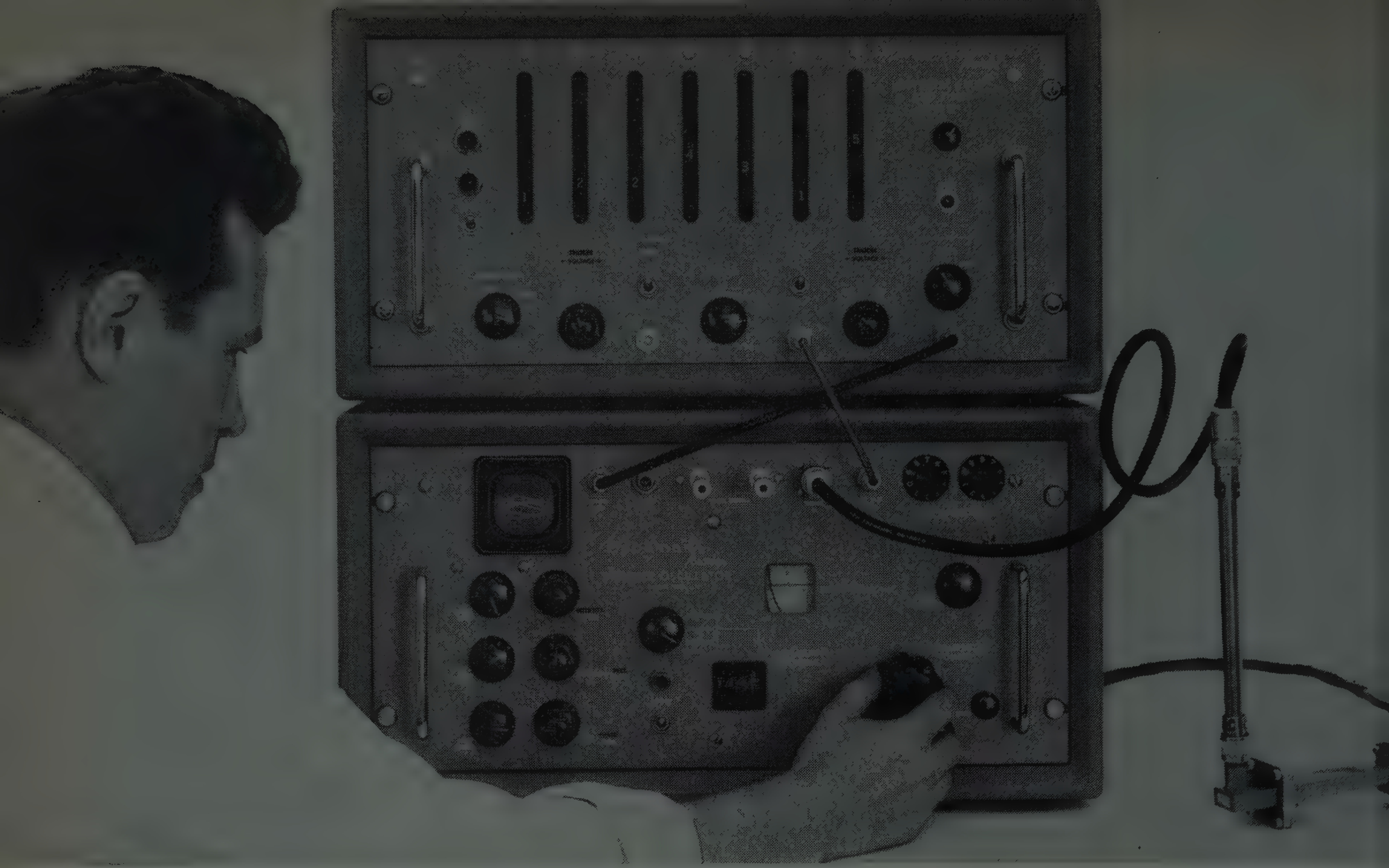

12,000 Mc

directly displayed by a counter

Model 7580 Transfer Oscillator (bottom cabinet) with Model 7370 EPUT and Timer (top cabinet):

Frequency measuring range	dc to 12 K Mc
Types of signals accommodated	CW, AM, FM pulsed r-f
Sensitivity	100 mv rms
Input impedance	50 ohms
Accuracy	up to ±3p in 10^7
Fundamental range of trans. osc	75 to 150 Mc & 7.5 to 15 Mc
Harmonics available	Up thru 80th
Stability of fundamental	.0001%/min

Four-step operation:

1. Tune to two adjacent zero beats identified by built-in oscilloscope display.
2. Read harmonic number on calculator dial.
3. Set rotary switches to harmonic number.
4. Read frequency indication directly from counter.

Prices:	
Model 7580 Transfer Oscillator	$1650
Model 7370 10 Mc EPUT & Timer	$1975

Model 7360J 2 Mc EPUT & Timer (price $1325) may also be used with the transfer oscillator.

Used in combination with the computing transfer oscillator in the cabinet beneath it, the 10 Mc EPUT® and Timer creates a *direct* decimal display of 12,243.15 megacycles generated by the small klystron at the right. How? The transfer oscillator contains a computing device which automatically calculates the harmonic number of a harmonic brought to zero beat with the frequency under test. Then, the gate time of the counter is multiplied by the harmonic number to produce a counter indication of actual klystron frequency. By eliminating all manual computations, the entire operation commonly takes less than one-fifth the time required using equipment previously available.

This assembly of two independent units, compatibly designed, offers an unprecedented combination of range, accuracy and convenience. The transfer oscillator can also be used with either of two other BECKMAN/Berkeley EPUT Meters currently in wide use.

data file
111
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For more information on this and other recent advances in digital frequency measuring techniques, write for the new Data File 111. Address department G-8.

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Heterodyne converters extend range of EPUT® Meter to 1000 Mc

Model 7570 Series Amplifier & Converters (bottom cabinet) used with Model 7170 EPUT Meter (top cabinet) or with Model 7370 EPUT & Timer (not shown).

Frequency measuring range with EPUT meter:

Model 7571 converter only	dc to 110 Mc
7571 & 7572 converters	dc to 220 Mc
7571, 7572 & 7573 converters	dc to 1000 Mc

Sensitivity (rms) & input impedance:

dc to 10 Kc	100 mv into 1M ohm
10 Kc to 10 Mc	1 mv into 1M ohm
10 Mc to 220 Mc	10 mv into 50 ohm
220 Mc to 1000 Mc	1 mw into 50 ohm

Video amplifier:

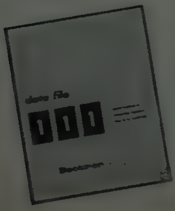
All converters are installed in the Model 7570 cabinet which includes a video amplifier used independently to increase the sensitivity of the counter. See 10 Kc to 10 Mc sensitivity above.

Prices:

Model 7570	$300	Model 7573	$ 500
Model 7571	$250	Model 7370	$1975
Model 7572	$250	Model 7170	$1675

Shown above measuring the output frequency of a 1000 Mc cavity resonator is a full complement of frequency converters operated with a 10 Mc counter. The bottom cabinet *permanently* houses all three converters covering the full range from 10 Mc to 1000 Mc. Initial requirements for a more limited range can be accommodated by installing only one or two converters — without affecting the ease of future expansion. Extraordinary sensitivity (see specs.) insures that loading effects will not distort measurements of weak signals.

Measurements are extremely easy to make. No tuning is required up to 220 Mc. Simply select range, couple signal, adjust output level with aid of "low-satisfactory-high" meter and read counter indication, adding reference frequencies. Percentage accuracy exceeds that of counter alone.



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The "370," which has an outside diameter of only .447", is available in eight standard styles with various mounting and terminal arrangements for soldered or screw attachment. Type 370 Button Micas come in capacity ranges from 15 MMF up to and including 2,400 MMF.

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ERIE Button Silver-Mica Capacitors are still the world's best for VHF and UHF applications and for commercial equipment, where properties of the mica dielectric and the design features exceed performance of other types of capacitors. Standard ERIE Button Micas exceed the requirements of characteristics B and D MIL C-10950-B.

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(Continued on page 74A)

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CUSTOMER SPECIFICATIONS FOR COMPUTER TUBES!

New tight specifications now are offered by General Electric for all commercial computer tubes

Specific performance limits on G-E computer tubes now make it possible for circuit designers to work with established tube values. Maximum reliability can be designed into equipment, with optimum capabilities known in advance for each tube type.

Carrying these performance limits are new, tight G-E computer-tube specifications that represent greatly improved quality. Part of this quality story is told by the more exacting control requirements for Type 5965 (right) and other computer tubes. Equally important are improved production techniques by General Electric. New materials, in-process controls, and manufacturing tests are employed.

Result: outstanding new quality *across the board* for G-E computer tubes! More than ever, they are the finest, most dependable tubes you can install. See your nearest G-E Receiving Tube office below for new customer specifications, now available!

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200 Main Ave., Clifton, N. J. Phones: (Clifton) GRegory 3-6387 (N.Y.C.) WI. 7-4065,6,7,8	3800 N. Milwaukee Ave. Chicago 41, Illinois Phone: SPring 7-1600	11840 W. Olympic Blvd. Los Angeles 64, Cal. Phones: GRanite 9-7765 BRadshaw 2-8566

TYPE 5965 . . . new G-E quality controls for this representative computer tube include:

Stricter attributes testing. In particular, plate current is held to much closer limits through more sensitive test procedures.

Combined defectives requirement has been included in both initial and life testing of attributes.

High-sensitivity check for intermittent tube shorts is an added test requirement.

Heater-cycling life test has been added.

Interface quality-control procedures have been widened in scope, and sample sizes have been increased.

Life testing has been broadened and extended, as summarized below:

1. Sample sizes have been increased 33 1/3%.
2. Now nine different life-test performance requirements, as against four previously.
3. Stability requirement on major operating characteristics has been added.
4. Longer life tests up to 5000 hours now are conducted regularly, to maintain a continuous surveillance of long-life performance.

The following General Electric tubes for computer service all are controlled and tested to new and superior standards of quality:

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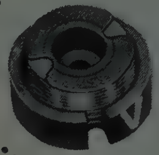
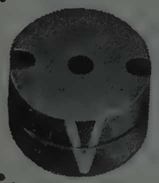
you can wind your filter coils
WITHOUT CORE ADJUSTMENTS
on
pre-adjusted filter cores

Typical Ferroxcube pre-adjusted pot core and bobbin.


Bobbin, wound with specified number of turns of wire for desired inductance, placed in pot core.


Assembly completed by placing second core over bobbin-and-core subassembly. Pot core aligned to within ±1% inductance by lining up V segments so that they form an unbroken V.

- guaranteed effective permeabilities within ±3%, ±2% or ±1% of specifications, instead of usual 10% to 50% spread
- measured, adjusted and grouped for magnetic characteristics at the factory
- a complete line of pot-type ferrite cores from ⅝" to 1¾" diameter, with bobbins and hardware for each size
- available in quantity to manufacturers of communications, telemetering and computer equipment

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(Continued on page 76A)

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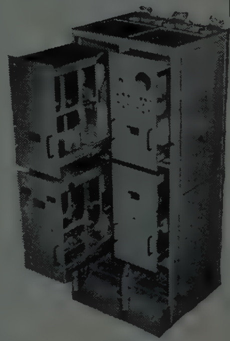

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TYPE 317 CHARACTERISTICS

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Passband—dc to 10 mc.

Risetime—0.035 μsec.

Sensitivity—0.1 v/div to 125 v/div, dc-coupled and ac-coupled—0.01 v/div to 0.1 v/div, ac-coupled only. Twelve calibrated sensitivity steps.

SWEEP RANGE

0.2 μsec/div to 6 sec/div. 22 calibrated steps from 0.2 μsec/div to 2 sec/div.

5-x magnifier increases calibrated sweep rate to 0.04 μsec/div.

TRIGGERING

Preset or manual stability control with amplitude-level selection, and fully-automatic triggering.

ACCELERATING POTENTIAL

10-KV on new Tektronix high-voltage 3-inch cathode-ray tube.

CALIBRATOR

Amplitude calibrator, 0.05 to 100 v in 11 steps, square-wave frequency about 1 kc.

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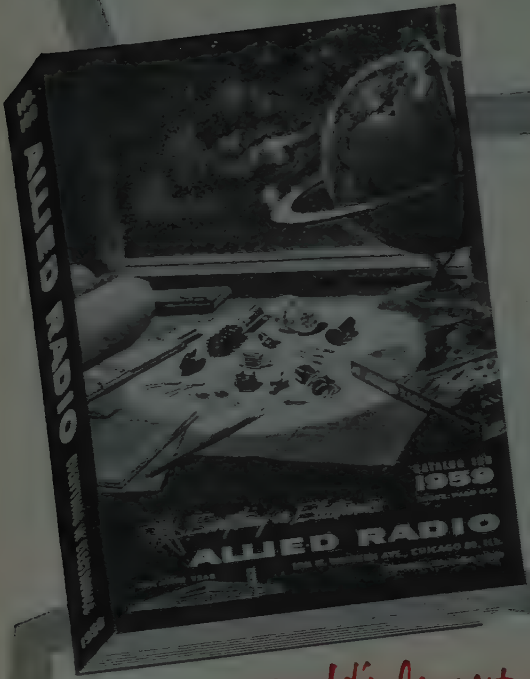

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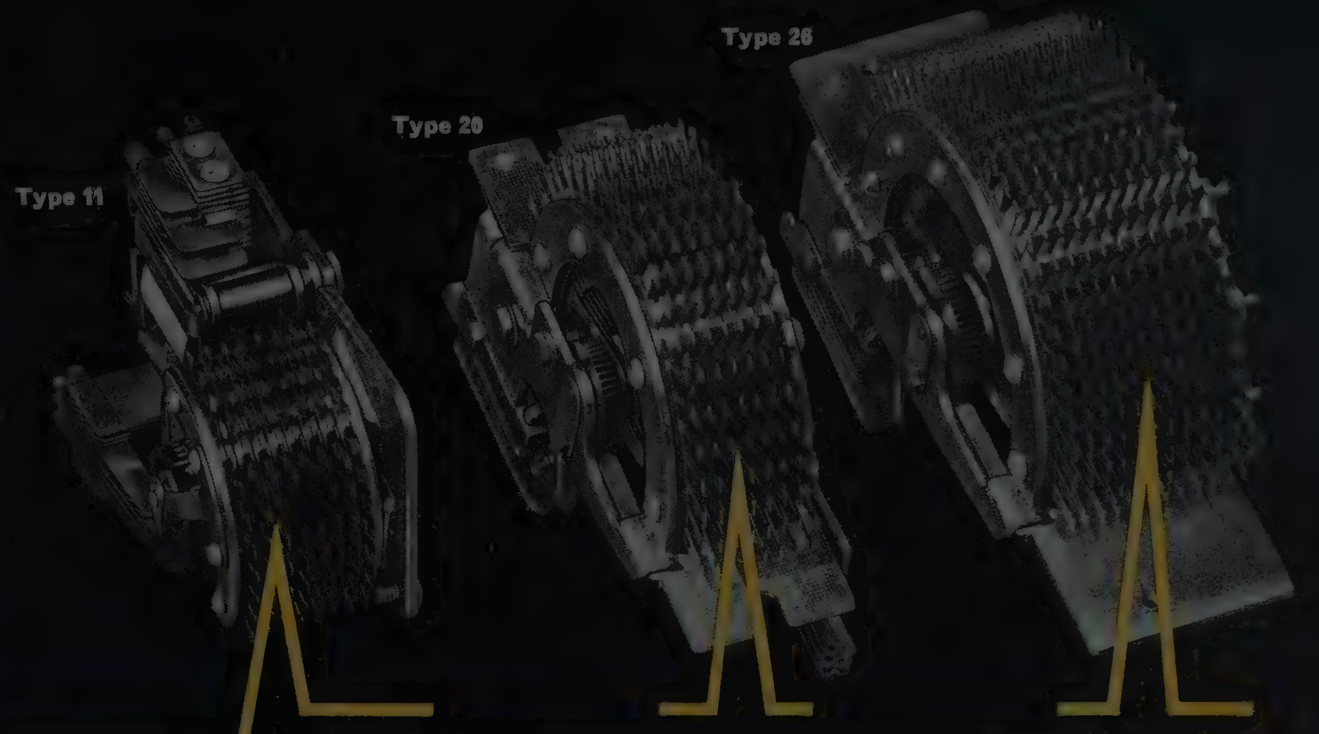

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100,000 megohms minimum between switch points and between each point and frame.

- ***STABLE INSULATION RESISTANCE***

Maintains 100,000 megohms minimum resistance over temperature range from —55°c to +85°c.

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Maintains low leakage characteristics in humid environment. Water absorption: 48 hours at 50°c, 0.5% (ASTM Test D570).

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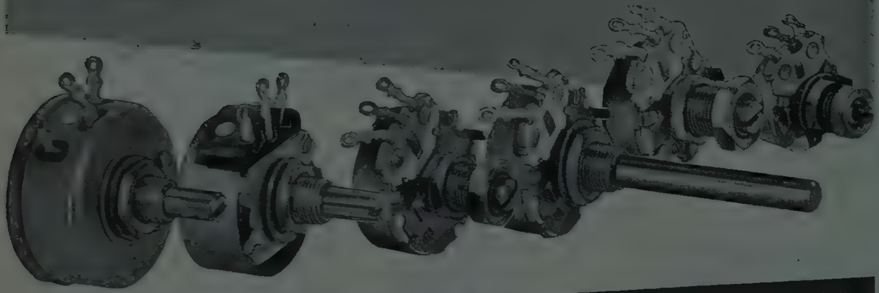

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(Continued on page 80A)

FOTOCERAM circuit board blanks are made photographically. All holes and shapes are produced by simple exposure to light, heat, and an etching operation.

This is a FOTOCERAM printed circuit

. . . an unusual new type of printed circuit board

Reliable through-plate holes • The good adhesion of the circuit runs applies also to the through-plate holes because both are produced with one plating operation.

Excellent resolderability • We have removed and resoldered components over twenty times on a FOTOCERAM board without damage to circuit runs or through-plate holes. And this is *without* using adhesives to bond the copper to the board.

Dimensional stability • Rigid structure of FOTOCERAM prevents unusual design considerations—eliminates problem of warp and twist.

Good adhesion • It takes 12-25 pounds to peel a one-inch copper strip from a FOTOCERAM board.

Exceptional pull strength • 1400 pounds per square inch.

No water absorption • FOTOCERAM'S nonporous—zero water absorption.

Non-flammable

No blisters • FOTOCERAM never blisters. We put it through repeated 15-second cycles of copper metallizing at 500°F. and could not find a single blister or sign of peeling or failure.

Other properties:

Dissipation factor		
	1mc @ 20°C.	0.006
	@ 200°C.	0.014
Dielectric constant		
	1 mc @ 20°C.	5.6
	@ 200°C.	6.3
Loss factor	1mc @ 20°C.	0.034
	@ 200°C.	0.088

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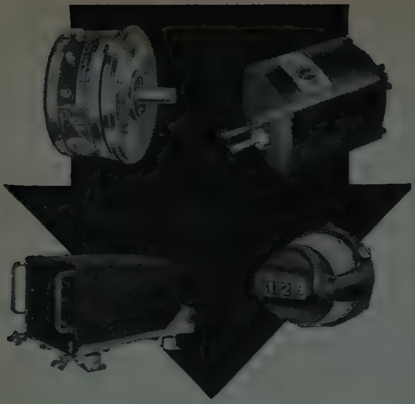

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- **MICROPOTS**
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(Continued from page 78A)

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Swartz, P. C., San Carlos, Calif.
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(Continued on page 82A)

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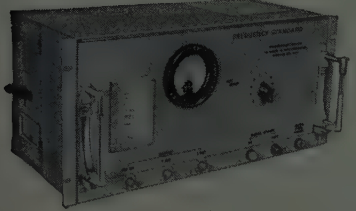

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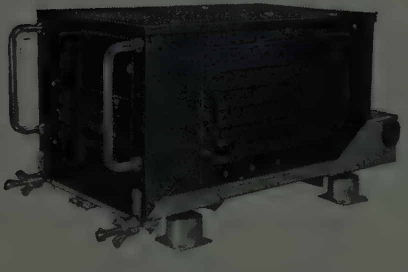

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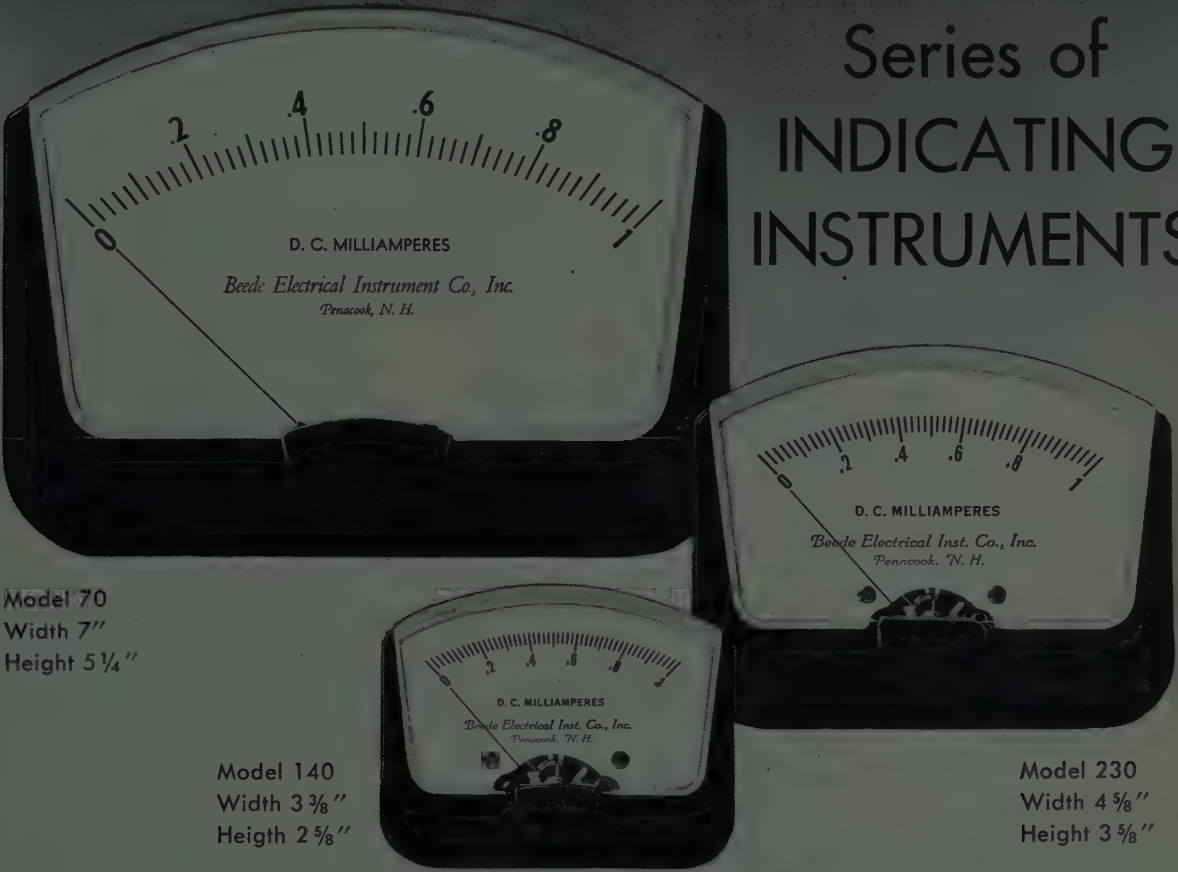

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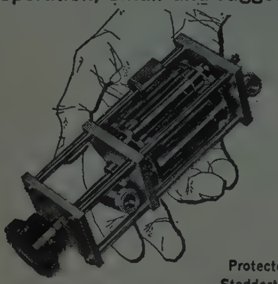

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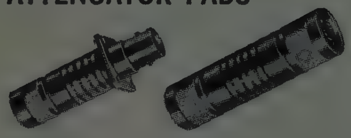

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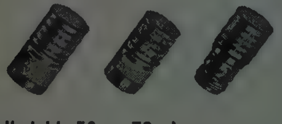

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Professional Group Meetings

ANTENNAS AND PROPAGATION

Boston—May 28

"Ionospheric Physics in the I.G.Y.," N. C. Gerson.

Syracuse—May 20

"Ferrite Modulators," Dr. Howard Scharfman, Raytheon Corporation.

AUDIO

Chicago—May 21

"RCA Compatible Color Television System," including tour of NBC Color TV Studios, W. C. Prather, WNBQ.

Cincinnati—June 24

Inspection trip and demonstration of WLW's new Rockwell Cathanode Transmitter and Crosley's Voice of America Facilities. (R. J. Rockwell)—Crosley Broadcasting Division of Avco, Cincinnati, Ohio.

Cleveland—May 15

"Qualitative Discussion on the Present Day Techniques Used in Obtaining Low Frequency Sound Reproduction in Speakers," Joseph Chernof, Jr., Bell Aircraft Corp.

AUTOMATIC CONTROL

Boston—May 12

"Application of Direct Drive Motors to Control Systems," S. A. Wingate and D. C. Smith, Detroit Controls.

BROADCAST AND TELEVISION RECEIVERS

Chicago—May 9

"Application of Transistors in TV Receivers," Andre Bourget, Warwick Radio Corp.

(Continued on page 86A)

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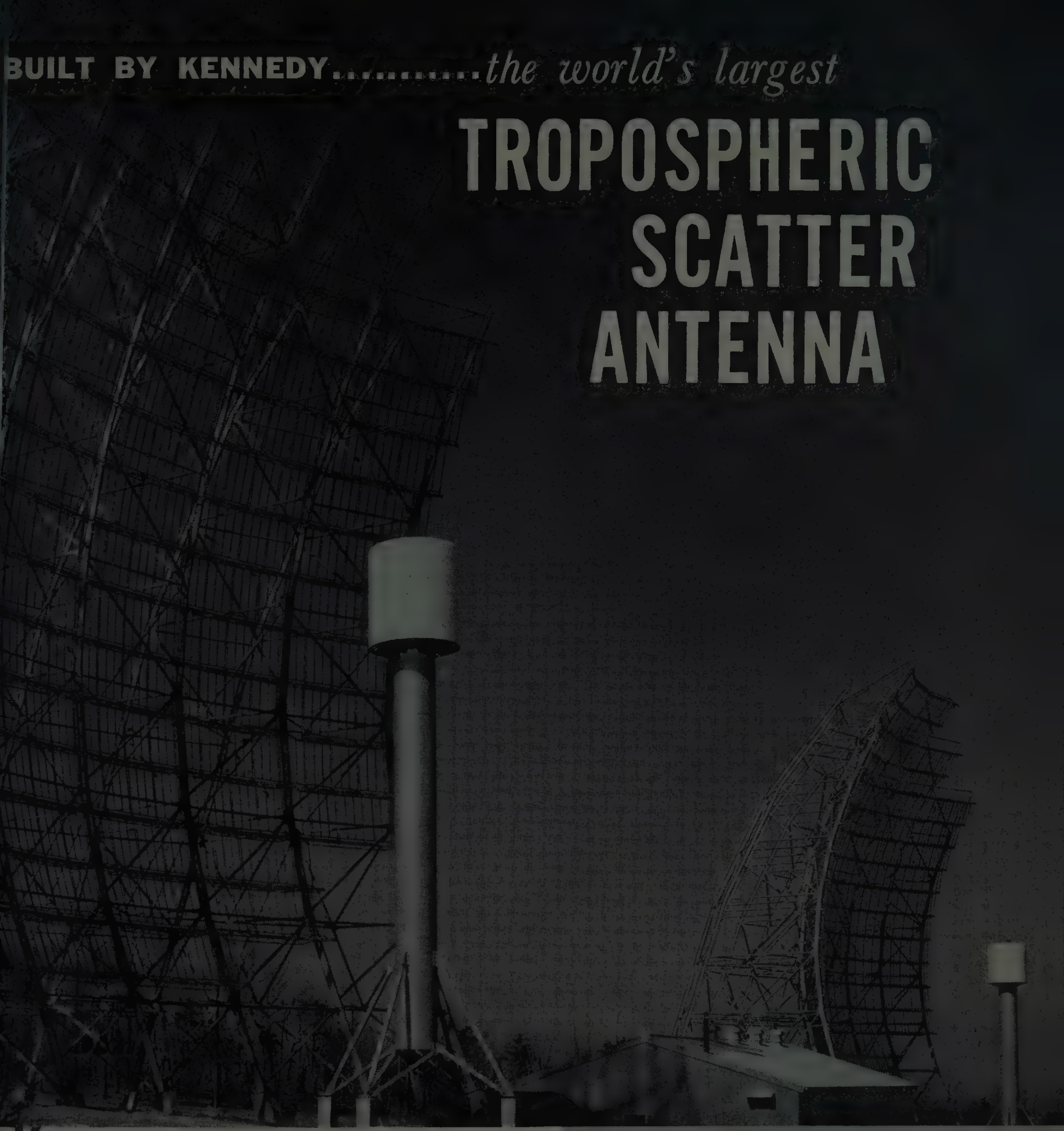

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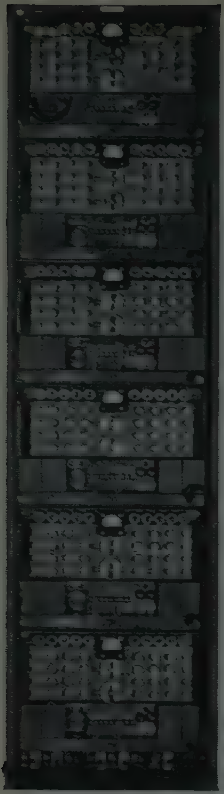

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Professional Group Meetings

(Continued from page 84A)

Broadcast Transmission Systems

Boston—May 15

"Practical Stereophonic Phonograph Records," R. E. Warn and E. A. Dickinson, Westrex Co.

Cleveland—May 14

"A Novel System for Feeding Single Tower AM, FM and TV Signals," A. G. Goodnow, Westinghouse Broadcasting Company; "The New KYW 50 KW Transmitter Installation," A. H. Butler, Westinghouse Broadcasting Company.

Omaha-Lincoln—June 14

Guided Tour of FCC Station.

Circuit Theory

Albuquerque-Los Alamos—March 20

"Remarks on Undergraduate Studies in Circuit Theory," C. S. Williams, Sandia Corp.

Chicago—April 11

"Circuit Parameters—What Are They?," G. I. Cohn, Illinois Institute of Technology.

Component Parts

Jt. N. Y., No. N. J., & L. I.—March 6

"The Evolution and Extension of Two Unit Printed Circuit Connectors," B. A. Jackson, U. S. Components, Inc.; "A New Family of Printed Circuit Connectors," H. E. Ruehlemann, Elco Corp.

Electron Devices

Los Angeles—June 16

"The Measures of Reliability," David Cowan, Hughes Products; "Semiconductor Diode Reliability—Evaluation and Control," Arthur Feldon, Pacific Semiconductors, Inc.

Jt. N. Y., No. N. J., & L. I.—May 8

"The Thyristor," Israel Kalish and Andrew Bosso, R.C.A. Semiconductor Division.

Jt. N. Y., No. N. J., & L. I.—February 5

"Plasma and Cyclotron Oscillations," Dr. M. Ettenberg, Sperry Gyroscope Co.

Electronic Computers

Binghamton—May 19

"The Twistor Memory Device," W. A. Barrett, Bell Telephone Labs.

Houston—May 27

"The IBM 704 Core Memory," Bill Martin, IBM Corporation.

New York—April 3

"Survey of Non-impact Electronic Printer," Dr. Herman Epstein, Teledynamics, Inc.

(Continued on page 88A)

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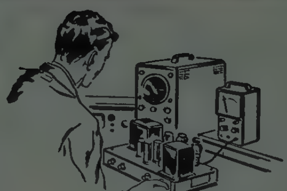

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Address ____________

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State ____________

Professional Group Meetings

(Continued from page 86A)

New York—March 5

"Use of Computers in Research," Dr. H. J. Grosch, IBM Corporation.

New York—February 13

"The Twistor, A New Solid State Memory Element," A. H. Bobeck, Bell Telephone Labs., Inc.

ENGINEERING MANAGEMENT

Los Angeles—June 17

"Technical Films—Luxury or Necessity," R. M. Murray, Hughes Aircraft Company; "The Problem of Executive Management in Scientific Business," Melville C. Branch, Jr., Ramo-Wooldridge Corporation.

ENGINEERING WRITING AND SPEECH

Boston—April 24

"The Mental Cramps of the Engineer Writer," E. H. Cameron.

INFORMATION THEORY

Los Angeles—June 19

"Correlative Processes in Communication and Control," Robert Kalaba, Rand Corp.

MEDICAL ELECTRONICS

Chicago—April 11

"Determination of Fracture Healing by Measurement of Sound Velocity Across the Fracture Site," I. M. Siegel and Theodore Fields, Veterans Administration Hospital.

Jt. N. Y., No. N. J., L. I., & Princeton—May 1

"Cinedensigraphy: A Technique for Radiographic Pulmonary Investigation," Dr. Maurice Marchal, Laboratoire de Radiologie.

Jt. N. Y., No. N. J., L. I., & Princeton—February 27

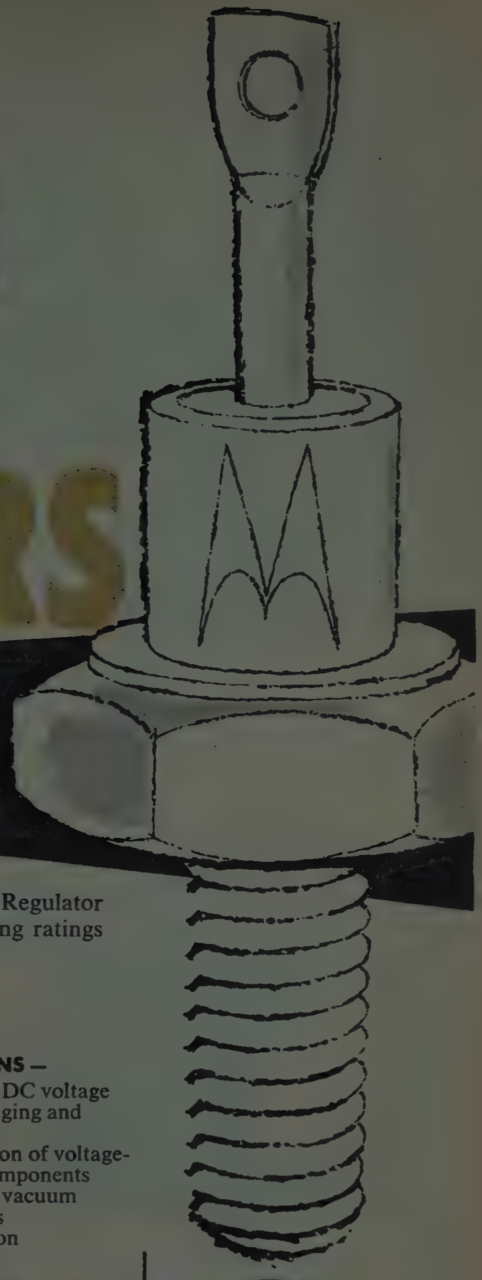
"Instrumentation Problems in Ballistocardiography," DeWitt Hendee Smith, Ballistocardiograph Laboratory.

Omaha-Lincoln—May 8

"Indicator Dilution Methods in Cardiovascular Diagnosis," Dr. T. F. Hubbard, University of Nebraska; "Live Animal Demonstration with 6 Channel Oscilloscope Monitoring Physiological Functions During Anesthesia and Surgery," Dr. John Barmore, assisted by R. A. Stratbucker, and Mr. and Mrs. Paul Leonard, all of Univ. of Neb. College of Medicine; "Short Distance Electrocardiogram Transmission Using Transistorized Radio Transmitting System," Dr. F. Lowell Dunn, Harold Beenken, and Ronald Loch, all of NU College of Medicine.

(Continued on page 90A)

NEW MOTOROLA ZENER REGULATORS



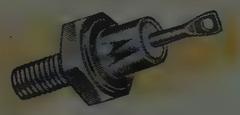
10 and 50 WATT types up to 200 VOLTS

Here's an entirely new Motorola product line . . . silicon junction Zener Regulator diodes produced under Motorola's extreme quality standards and offering ratings and characteristics not previously obtainable.

- Very high power ratings — both 10 and 50 watt types available.
- Wide voltage range — up to 200 volts in both 10 and 50 watt types.
- Very low Zener impedance limits.
- "Soft" or unstable Zener knees eliminated — by impedance limits at 5 mA for 50 watt type . . . at 1 mA for 10 watt types.
- Forward characteristics controlled — for applications requiring conduction in both directions.
- Available with either anode or cathode connected to case.
- Conservatively rated — excellent long-time stability.
- Designed for military usage — Operating and storage temperature range —65°C to +175°C.
- Standard packages —
  - **10 WATT TYPES** welded, hermetically sealed, metal to glass, Jetec package.
  - **50 WATT TYPES** plug-in or solder-in TO-3 package with series interlock construction for protection against overvoltage on load.

TYPICAL APPLICATIONS —

Regulation of DC voltage
DC level changing and coupling
Surge protection of voltage-sensitive components
Regulation of vacuum tube heaters
Arc suppression



10MZ SERIES
10 watts @ 55°C

50MZ SERIES
50 watts @ 55°C

FOR COMPLETE TECHNICAL INFORMATION

concerning these new Zener Regulators, contact the nearest Motorola regional office or

MOTOROLA, INC.,
5005 East McDowell Road, Phoenix, Ariz.
BRidge 5-4411. Teletype Px 80.

"DEPENDABLE QUALITY - IN QUANTITY"

MOTOROLA SEMICONDUCTORS

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Regional Offices

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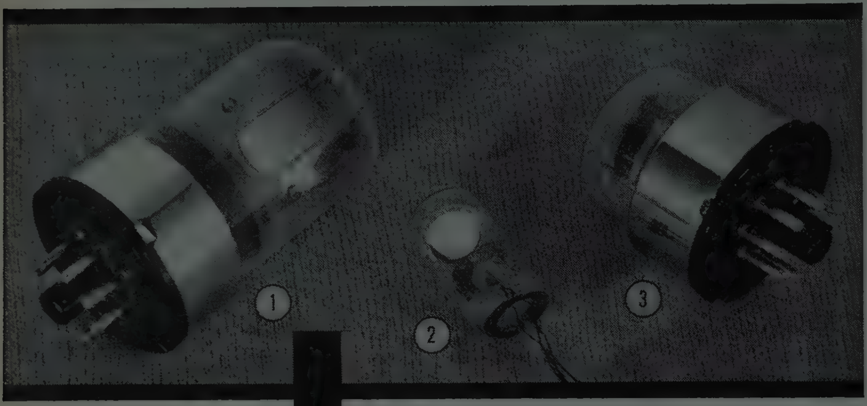
Frequency JK PRODUCTS Management

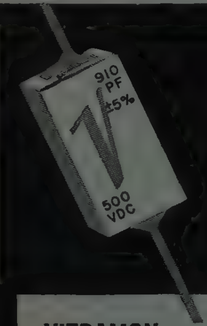
Ultra-Stable, Shock-Mounted Glasline Crystals



1. G-12A-1000 kc
2. G-6AS-5 mc
3. G-12AS-1000 kc

G-6AS and G-12AS meet stability demands of 1 PPB/day. Frequency tolerance ± 1 PPM. Secular stability 1 PPB/day. Shock—1 PPB at 20G impact. Write for data sheets.

THE JAMES KNIGHTS COMPANY—Sandwich, Ill.



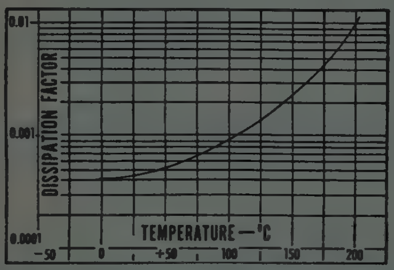
Vitramon® CAPACITORS

will help you build

WIDE TEMPERATURE RANGE

...into your circuit systems

VITRAMON capacitors have low dissipations from —55°C to 250°C.



Two materials — a monolithic block of porcelain enamel and fine-silver electrodes — fused into one strong, stable, efficient and effectively homogenous **RELIABLE** unit.

VITRAMON capacitors . . . fine-silver electrodes fused to pure porcelain enamel dielectric . . . operate predictably over a range of more than 300°C and come back from the extremes—unaltered.

WIDE TEMPERATURE RANGE?

YES! PLUS . . .

RUGGED LOW LOSS STABLE VAPORPROOF LOW NOISE MINIATURE

The biggest names in electronics use VITRAMON capacitors in guided missiles, jet ignition, proximity fuses and in radar, servo, guidance, fire control, telemetering and carrier telephone systems.

If substitutes are not good enough... if you need the best... write today!

Vitramon® Incorporated

BOX 544P • BRIDGEPORT 1 • CONN.

Professional Group Meetings

(Continued from page 88A)

MICROWAVE THEORY AND TECHNIQUES

Albuquerque-Los Alamos—June 26

"Second Lecture on Noise," Dr. B. L. Basore, Dikewood Corporation.

Albuquerque-Los Alamos—May 5

"Notes on Noise," Dr. Bennett Basore, Dikewood Corporation.

Boston—May 15

"Optimum Filter Design by Input Impedance Measurements," A. E. Sanderson, General Radio Co.

Los Angeles—June 12

"Microwave Application of Gas Discharges in a Magnetic Field," O. T. Fundingsland, Sylvania Electronic Defense Laboratory; "A New Concept in Microwave Gas Switching Elements," Ray S. Braden, Bomac Laboratories, Inc.

Syracuse—May 20

"Ferrite Modulators," Dr. Howard Scharfman, Raytheon Corporation.

MILITARY ELECTRONICS

Central Florida—June 26

"Vanguard Operations at the Atlantic Missile Range," Dan Mazur, Naval Research Laboratory; "High School Science Club Activities," Allen Womack, Melbourne High School Science Club.

Central Florida—February 14

"Planning and Programming of Electronic Research and Development in the U. S. Air Force," A. W. Sieck, Radiation, Inc.

Los Angeles—June 17

"Review of the Pros and Cons of the Defense Department Reorganization," J. F. Bryne, Motorola, Inc.

NUCLEAR SCIENCE

Albuquerque-Los Alamos—May 26

"Instrumentation and Control for SERE," James G. Lareau, Sandia Corporation.

Chicago, May 9

"A Commercial Sub-Critical Reactor for Nuclear Training," Poh Shien Young and Philip Shevick, Nuclear-Chicago Corp.

PRODUCTION TECHNIQUES

Los Angeles—June 25

"Vacuum Deposition of Electronic Components," Earl R. Olson, Servomechanisms, Inc.

(Continued on page 93A)

1K20 Series X and K Band Klystron (left)
1K125C Series C Band Klystron (right)

Eimac Announces...
Six New Ceramic Reflex Klystrons

Two important frequency ranges in the C, X and K bands are now covered by Eimac ceramic reflex klystrons. Eimac's advanced stacked ceramic design gives these tubes exceptional ruggedness and frequency stability.

The four new tubes of the 1K20 series cover 8500 to 11,700 Mc. at power levels to 50 milliwatts. These tubes are specifically designed for use in the severe vibration and temperature environment of air-borne and missile radar systems. They will withstand vibration levels of 15G in any reference plane with less than 100 kilocycle frequency deviation. Rated for use at any altitude, the 1K20 series tubes are conservatively rated at +250°C seal temperature. A new non-contacting, non-microphonic tuner permits noise-free tuning of the tubes through their complete ranges. Low beam voltage requirement and simple radiation cooling minimize the weight and complexity of associated equipment.

Two new C-band tubes comprising the 1K125 series cover 3700 to 5000 Mc. Power levels up to 2 watts make these tubes ideal for reliable broadband point-to-point communication. Tuning by dielectric slug rather than variable RF gap avoids sensitivity to shock and vibration. Integral-finned cooler and higher operating temperature ratings minimize cooling requirements.

Eimac know-how in the field of ceramic-metal tube design now brings compactness, ruggedness, high performance and reliability to these important microwave frequencies.

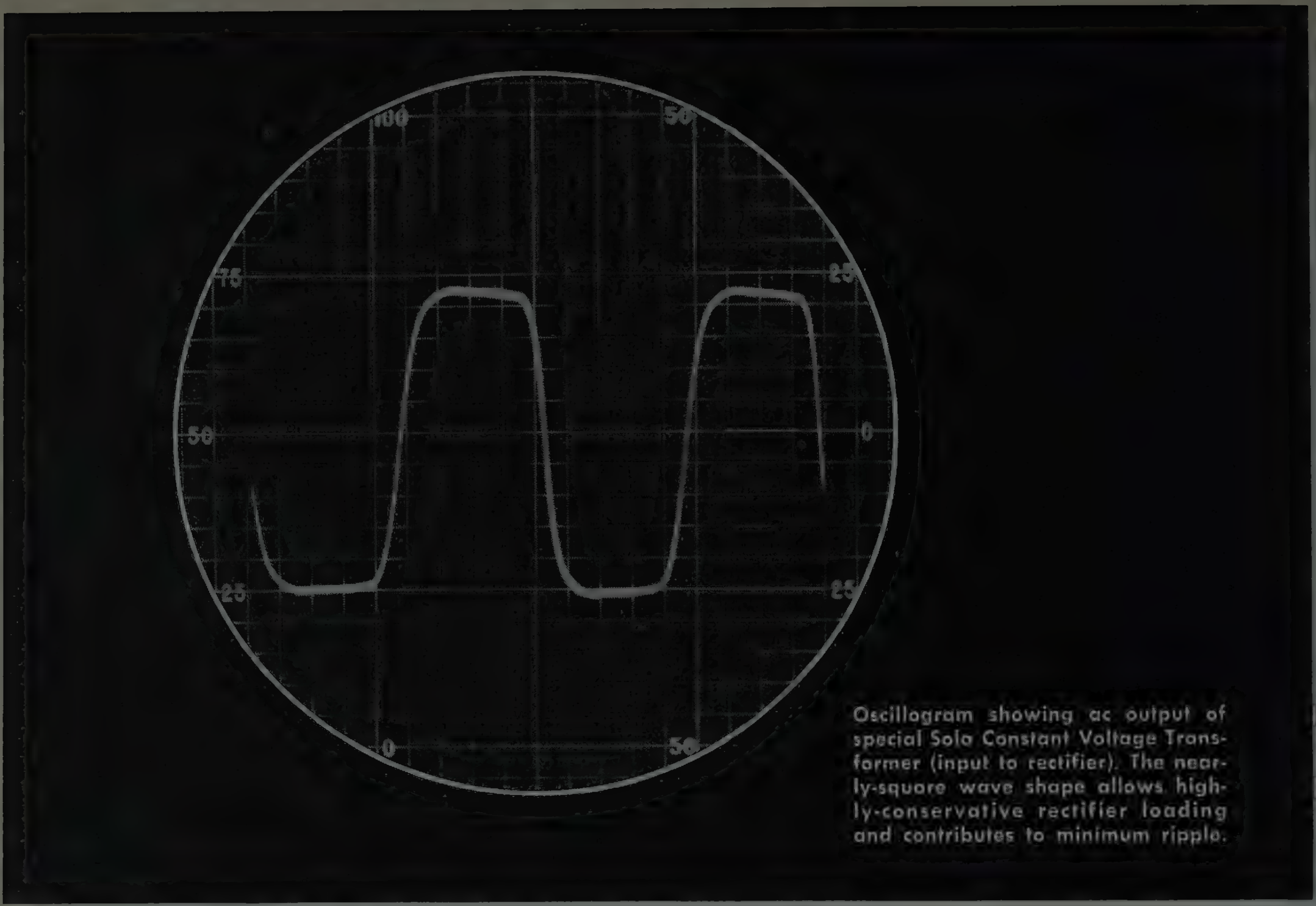
For further information request a copy of the brochure "A New Line of Eimac Reflex Klystrons"

EITEL-McCULLOUGH, INC.
SAN CARLOS, CALIFORNIA
Cable Address: EIMAC, SAN BRUNO
Eimac First for ceramic reflex klystrons

Eimac®

GENERAL CHARACTERISTICS

Type	Freq. Range Mc.	Beam Voltage	Power Output Range	Reflector Voltage
1K125CA	3700-4400	1000 Vdc	1.5 to 2.0 W	0 to —500 Vdc
1K125CB	4400-5000	1000 Vdc	2.0 to 2.3 W	0 to —500 Vdc
1K20XS	8500-9300	300 Vdc	25 to 50 mW	0 to —250 Vdc
1K20XK	9200-10,000	300 Vdc	25 to 50 mW	0 to —250 Vdc
1K20XD	10,000-10,800	300 Vdc	25 to 50 mW	0 to —250 Vdc



Oscillogram showing ac output of special Sola Constant Voltage Transformer (input to rectifier). The nearly-square wave shape allows highly-conservative rectifier loading and contributes to minimum ripple.

EFFICIENT, regulated DC power supply

Can you use a ±1% regulated dc power supply that has no filter choke drops . . . that has an unusually low ratio of size and weight to power output? If so, consider a Sola Regulated DC Power Supply.

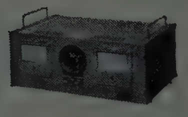
This unique power supply combines: 1) a Sola Constant Voltage Transformer, 2) a semi-conductor rectifier, and 3) a high-capacitance filter without choke.

The special Sola transformer output (illustrated above) is virtually a square wave, peak to rms. ratio, approximately 1.06 to 1. It not only minimizes ripple, but limits peak voltage to rectifier.

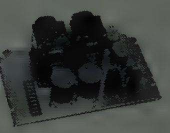
The current-limiting action of the Sola transformer permits the use of enormous capacitance for filtering, by controlling capacitor charging, thereby protecting it, and the rectifier junctions.

This dc source will give you exceptional performance on intermittent, pulse, and variable loads. The Sola regulated dc supply is very reliable, simple, and compact. It's moderately priced.

Fixed output — six ratings available from stock



Adjustable output — six ratings from stock



Custom-designed units produced to your specs

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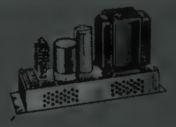
Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

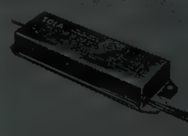
SOLA

CONSTANT VOLTAGE TRANSFORMERS



REGULATED DC POWER SUPPLIES

MERCURY LAMP TRANSFORMERS



FLUORESCENT LAMP BALLASTS

Professional Group Meetings

(*Continued from page 90A*)

Jt. N. Y., No. N. J., & L. I.—March 13

"Production Techniques for Etched Wiring," E. J. Lorenz, International Business Machines.

TELEMETRY AND REMOTE CONTROL

Central Florida—May 22

"Compact Telemetry Direct Writing Recorder," Andrew Malcolm, Centronix Inc.

Detroit—May 21

"Systems Thinking in Telemetry," C. H. Hoeppner, Radiation, Inc.

VEHICULAR COMMUNICATIONS

Chicago—May 9

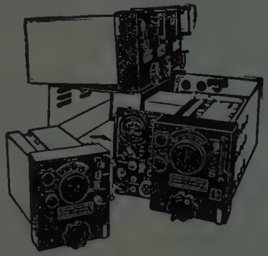
"An Organized Approach to Two-Way Radio Systems Design," A. R. Patzlaff, Motorola, Inc.

Jt. N. Y., No. N. J., & L. I.—June 10

"Successful Operation with Split Channels," J. R. Neubauer, Radio Corporation of America.

AN/APT-5 TRANSMITTERS

Make excellent power signal generators for the range 300-1625MC., rated at 58 watts CW RF at 500MC. Contains blower-cooled 3C22 in re-entrant cavity with precision cathode, plate and loading controls, plus 6 tube AM modulator and amplifier flat from 50KC to 3MC. (easily converted to audio) with phototube noise generator. 115 volt 60 cycle filament supply. New, in export packing, with matching special plugs, lecher line, alternate feedback assembly, manual, audio conversion instructions and technical data, at $250.00. Limited stock.



AN/APR-4 RECEIVERS

with all five Tuning Units covering 38 to 4,000MC.; versatile, accurate and compact, the aristocrat of lab receivers in this range. Complete with wideband discono antenna, wavetraps, 100 page manual, plugs, cables and mobile accessories as required.

The AN/APR 4 has been our specialty for over ten years. Over 40 hours of laboratory time is invested in each complete set immediately prior to shipment, so that we can not only guarantee it to pass A-N specifications, but to have the inevitable mass-production irregularities corrected and the latest improvements added. We maintain a complete stock of spare parts and expect to service our customers' sets indefinitely. Write for data sheet and quotation. Also, prior models SCR-587A, RDO and AN/APR-1.

TEST EQUIPMENT

of highest quality, new and reconditioned, military surplus and top commercial brands in stock at money-saving prices. Let us quote to your requirements.

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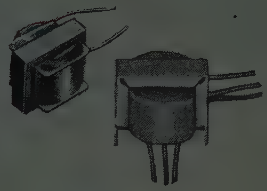
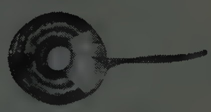
TRANSFORMER NEWS **FROM TRIAD**

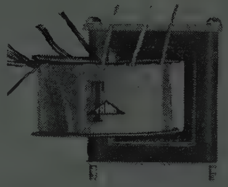


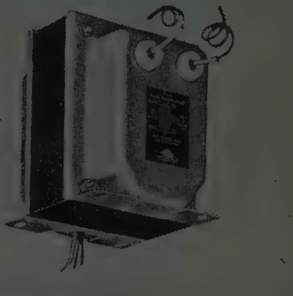
TRIAD OFFERS 940 STOCK ITEMS, PLUS SPECIALS

Shown, right, are several of the 940 transformers immediately available from our catalog. Many specific items are made to meet military specification requirements, and all are made to meet Signal Corps standards. (See below.) You name the application—Triad has the solution. Occasionally requirements are so unusual that no Triad standard catalog transformer will serve. Then we build to special requirements, using the most modern equipment in the industry.

NEW CATALOG OUT—General Catalog TR-58 on Triad Quality Engineered Transformers contains all Triad types, plus specifications and prices. We will gladly mail you a copy on request.







TRIAD

RIQAP

(Reduced Inspection—Quality Assurance Plan) Your own incoming inspection and field service requirements are reduced to a minimum when you specify Triad. All Triad Transformers are manufactured under this Signal Corps approved plan for quality assurance. RIQAP is awarded only to those companies who continue to maintain Signal Corps standards.

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AUDIO AMPLIFIER

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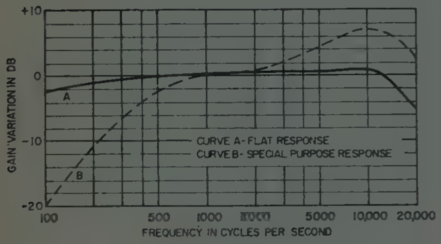
Speaker, Speech, Line, Cuing, Monitoring, Intercom or Utility Amplifier.

Consumes little more power than an electric clock—can be connected and left on permanently.



SPECIFICATIONS

Gain:	Matched input—60 db Bridging input—39 db
Distortion and Power Output:	1% or less, 200—10,000 cycles at 1/2 w output.
Hum and Noise:	40 db or better below 1 millwatt.
Impedances:	Input—150/250, 500/600 matched, or 7,000 ohms bridging. Output—16/4, 150/250, 500/600 ohms, or as specified.
Power:	105/125 volts, 47-63 cycles, 3 watts.
Size:	19" wide, 1-3/4" high, 9" deep.

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Silver Spring, Md.

Section Meetings

AKRON

"Our Country's Space Program," F. H. Kierstedt, Jr., Goodyear Aircraft; 6/17/58.

ALAMOGORDO-HOLLOMAN

"Simulation and Calibration Laboratory," narration, field trip, J. Ward, Air Force Missile Development Center; 6/16/58.

ALBUQUERQUE-LOS ALAMOS

"The Application of Electronics to Physical Chemistry," R. Mueller; 5/2/58.

"Computation of Atmospheric Refraction by Ray Tracing and Comparison with Observed Results," W. L. Anderson; "Determination of Instantaneous Junction Temperatures in Power Transistors under Pulsed Conditions," J. D. Reese; "Transistor Distributed Amplifier," B. J. Harper; "Automatic Circuit-Data Retrieval," A. H. Koschamann; 5/22/58.

Annual Picnic, installation of Officers; 6/14/58.

ATLANTA

Tour of Telephone Company facilities; 5/23/58.

"The Overall Operations of IBM Data Processing Machines," R. G. Wyatt, IBM; 6/27/58.

BOSTON

"Some Problems in Space Technology," H. G. Stever, MIT; 5/20/58.

CENTRAL FLORIDA

"Management and Engineers," H. N. Morris, RCA; 6/19/58.

CHICAGO

"The Apple Color Television System," G. Pratt, Lansdale Tube Corp.; 12/13/57.

"Design Aspects of a Small Desk Side Computer," W. K. Betts, IBM; 1/10/58.

"Man in the Void," C. F. Gell, Air Crew Equipment Lab.; 1/12/58.

"New Developments in Management and Administration of Interest to the Professional Engineer," R. K. Burns, Univ. of Chi.; 2/14/58.

"A Ferrite Logic Element," B. R. Budney, Allen-Bradley Co.; 3/14/58.

CLEVELAND

"Higher Power Frequencies for Fluorescent Lighting," J. H. Campbell, G. E. Co.; Joint Meeting with Akron Section; 4/15/58.

Student Papers: "Application of Boolean Algebra to Electrical Circuits," D. V. Buyansky, Case Inst. of Technology; "Design and Development of a Turing Machine," J. L. Irwin, Case Inst. of Technology; "VHF-UHF Terminations for Power Measuring," J. Smetana, Fenn College; "Method of Testing Junction Transistors in Grounded-Emitter Connections," J. V. McNicholas, John Carroll Univ.; 5/8/58.

"Problems Incidental to the Development and Design of Heathkits," B. Heyning, The Heath Co.; 5/8/58.

COLOMBIA

"The Physics of Music and Hearing," a tapescript, A. Villegas, F. Garbrecht, RCA; 5/11/58.

"Switching Centers and Memories," M. Kunz, Philips Telecommunication Industries; 6/27/58.

COLUMBUS

Annual Meeting, Installation of Officers; 6/6/58.

DALLAS

"Review of Activities for the Past Year," C. F. Seay, Jr., Collins Radio Co. "Challenging Year Ahead," J. Albano, Chance Vought Aircraft; 6/13/58.

EGYPT

"High Power Medium Wave Transmitters," M. H. Mahmound, Cairo Univ.; 6/18/58.

EMPORIUM

"History, Theory and Testing of Bell Aircraft Automatic Landing Systems," F. Powell, Bell Aircraft; Talk by Donald G. Fink, IRE President, 6/17/58.

FORT HUACHUCA

"Reorganization of the Department of Defense," J. Byrne, Motorola Inc.; 6/23/58.

(Continued on page 102A)

For
Missile
Testing
and general use

30 to 300 Amps

- Closely Regulated
- Fast Response
- Underwriters Approved
- Rigid Quality Control

CHRISTIE
SILICON
POWER
RECTIFIERS

Available in Industrial and Military types. Military type meets specs MIL-E-4970 and MIL-I-6181. Other stationary and mobile styles available up to 1500 Amps.

Write for Bulletin AC-58-A

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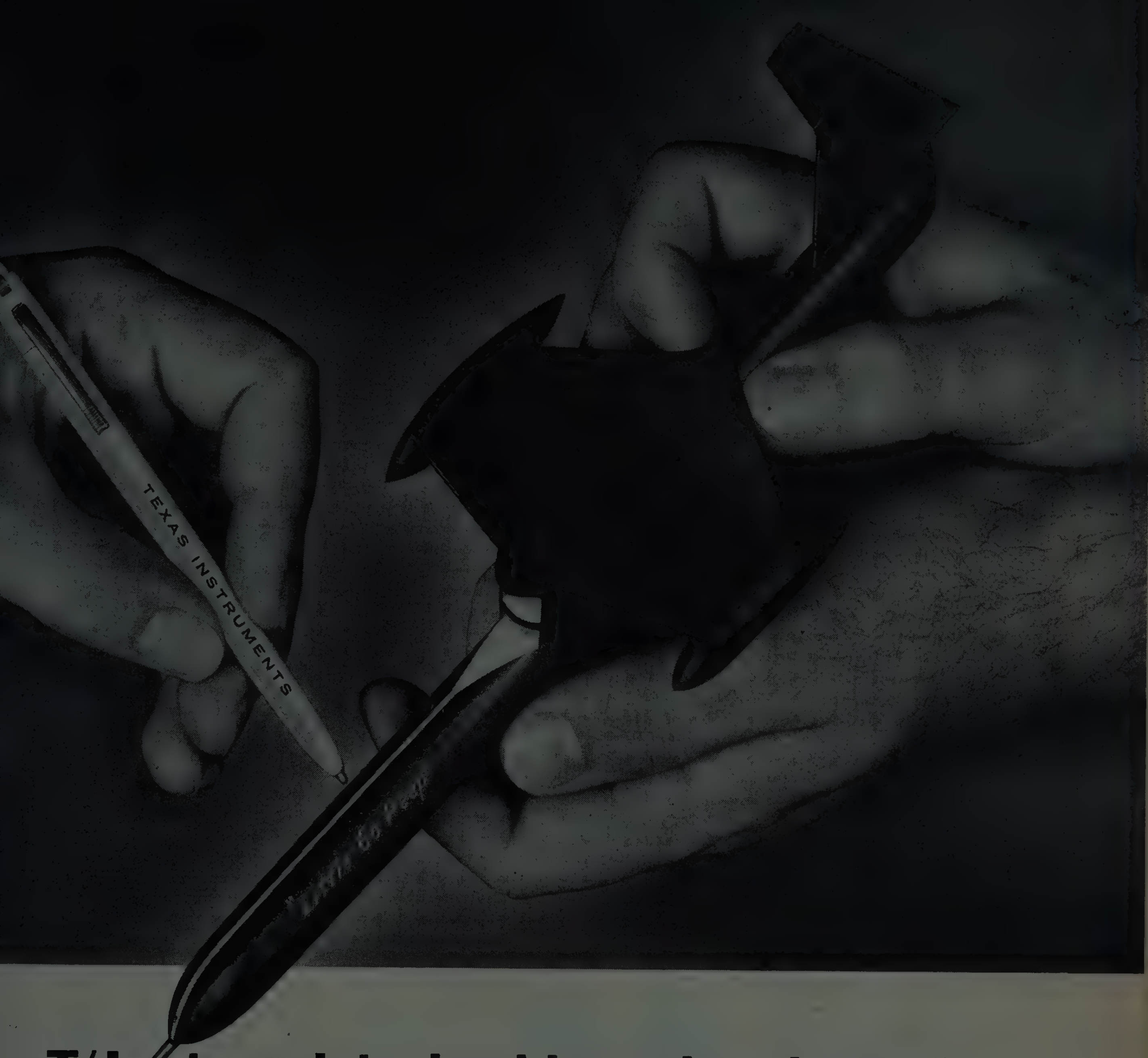
Over a Quarter Century of Rectifier Manufacturing



T/I transistorized 'peeping drones' see better...fly farther

ansistorized radar... and other Texas Instruments ectronic eyes" can peg the shape, location, motion, heat, and gnetic character of "targets of opportunity"...*relaying this al data for action in those brief moments that the opportu- y exists!* In manned or unmanned reconnaissance aircraft, s light, tough and compact electronics save fuel, space and ght while trimming maintenance and logistic problems. Discussion of this advanced reconnaissance capability can arranged on short notice. Authorized industrial or military sonnel write or wire: Service Engineering Department...

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research/design/development/manufacture

6499
RCA
RADIOTRON
ELECTRON
TUBE

Lewyt Coordinate Data Transmission equipments for SAGE uses RCA Radechons.

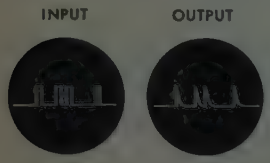
RCA-6499 RADECHON: Charge Storage Tube, Single-Beam, Barrier-Grid Type; Non-Equilibrium Writing and Capacitance-Discharge Reading. One of a line of RCA Radechons.

5 *ways*
RCA RADECHONS
handle electronic data... *effectively*

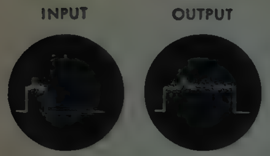
Can you name more?

Designed to "take in" electronic data—store it from microseconds to minutes—*then release the information at the same rate or at different rates,* RCA Radechons can play a key role in electronic data-processing systems for industry and the military.

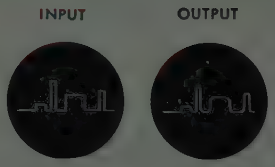
Read what these remarkable RCA Radechons can do for you—and how they do it:



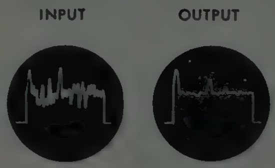
IN DIGITAL DATA STORAGE SYSTEMS, the Radechon acts as a high-speed, random-access, high-capacity memory element.



IN TIME-BASE CONVERSION APPLICATIONS, the Radechon releases a stored signal at a rate different from the input rate—as may be required in systems for the transmission of video signals over telephone lines, or in certain systems involving audio-signal multiplexing.



IN SIGNAL DELAY APPLICATIONS, the Radechon stores a signal burst—then releases it after delay periods from microseconds to minutes.



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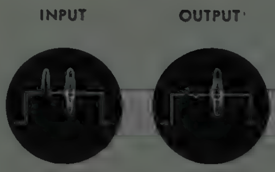

IN FIXED-SIGNAL CANCELLATION APPLICATIONS, the Radechon compares successive signals. Originally designed for "line-by-line" Moving Target Indicators, the Radechon also can be used in "area" MTI systems.

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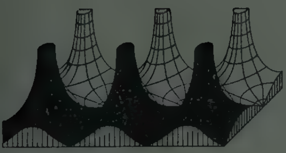
Electron Tube Division ***Harrison, N. J.***

September, 1958
Vol. 46 No. 9
Proceedings of the IRE

Poles and Zeros



D-Day in Engineering Education? This is written under a cloud of discouragement created by attendance at the annual convention of the American Society for Engineering Education at the University of California in Berkeley. The lejection comes not from attendance at any of the sessions of the Electrical Engineering Division (chairmanned by former IRE Director Eastman), nor as a result of visits with E. E. Department Head John Whinnery (present Director-at-arge) but from conversations with other engineering teachers nd administrators and attendance at certain sessions.

In Year I A.S. (After Sputnik) it seems appropriate to be liscouraged over the future of engineering and of our world fter attending a session of engineering teachers where it was necessary ardently to argue the desirability of graduate work or the engineer, and that a graduate degree should not be ased upon the development of specialized technical abilities, ut rather as a further deepening and broadening of the scientific base of the student. To listen to other arguments justifying the retention of a freshman course in surveying for all ngineers as training in measurement, without introducing rror theory or recognition that you may measure things you cannot see, or arguments on the need for a lengthy drawing course by stating that the student will then know the standard symbols for screw threads, or a shop course because he vill then learn to design parts that fit, is certainly disheartening. Especially so when we face this great and once-in-many-ifetimes opportunity to uplift the whole profession by making t a study of the science of nature as against training in technique. In the future it is not going to be enough to know how t *was* done—the problems of tomorrow have never been olved before.

While we admit our evolution from the early civil engineers, we wonder how long it will be before some of our educators recognize that we are not ALL civil engineers; that lectronics, rockets, and research have introduced a whole ew dimension to the spectrum of engineering knowledge, vhere conception and design of ideas may be of equal value to isualization and design of structures.

The widening of this spectrum of engineering knowledge s going hand in hand with increased utilization of mathematics. The fields which are moving and solving the new roblems for tomorrow seem to be the fields in which mathematical proficiency is at its highest level of advance—and we enture a theorem without further proof: A field of engineering can advance only as fast as its members acquire mathematical proficiency. How can members of a field be expected o understand what mathematics can do for them when they ave no proficiency in mathematics? How can they realize hat the electronic computer can now solve insoluble problems of an earlier age? Or that a mathematical analysis can often save kilobucks and kilominutes otherwise to be expended in the wrong experiment?

Take mechanical engineering as an example (*note:* always choose a field which is not your own) where in only recent years has the differential equation been studied, and where the partial derivative is still of somewhat questionable ancestry. Theoretical progress is just now really beginning, whereas electronics with its longer history of mathematical study now has graduates who are mathematics majors as well as engineers, and teachers to whom Laplace, Fourier, Bessel, Riemann, Cauchy, are old buddies.

Can the profession of engineering long remain divided, with members in one segment as unable to talk to other segments as if their languages were Aramaic and bebop, with some schools well advanced in the teaching of the science formerly contained in classical physics, and other schools still concerned with the apparatus and hardware of a swiftly passing day?

Are the engineering teachers, the engineering schools, and the engineering profession, at the point of decision—to choose between surveyors of technique or purveyors of science as teachers, hardware or ideas as our course material, drawing or mathematics as our language, and technicians or engineering scientists as our output? Which is it going to be?

Nothing Really New? Certain evidence indicates that history may have a repetition rate of about 2.5 per century. Microwaves returned in 1940 after original investigation before 1900, the crystal diode lived in 1900 and again in 1940, and now we are seeing a return of the battery almost forty years after its heyday in the early 1920's.

Which reminds us that our first battery experience came with the soldering of fifteen flashlight cells into a candy box to beat the price of those 1920 B batteries. We learned that battery life was inversely proportional to length of soldering iron contact, which was inversely proportional to the cleanliness of the iron, which was some never-determined function of the gas burner adjustment on the kitchen stove.

Be that as it may, the review paper on batteries in last month's issue is timely as we move into the transistor and solar-cell era. Besides, you asked for it—more review papers, that is.

Number Ninety-Nine! To show that the IRE is aware of progress in all fields from polyethylene to polarization to politics, may we remark that the Executive Committee recognized the importance of Alaska four days *before* it was approved as the forty-ninth state, by recommending the formation of the Anchorage IRE Section as Number 99. Greetings, polar bears!—J.D.R.

Donald B. Sinclair

Director, 1958

Donald B. Sinclair (J'30–A'33–M'38–SM'43–F'43) was born in Winnipeg, Manitoba, Canada, on May 23, 1910. He attended the University of Manitoba from 1926 to 1929, and worked part-time as a radio operator for Western Canada Airways. He then transferred to Massachusetts Institute of Technology, where he received the degrees of S.B. in 1931, S.M. in 1932, and Sc.D. in 1935. During this period he was enrolled in a cooperative course in electrical engineering, and worked at the New York Telephone Company, the Western Electric Company at Hawthorn, and the Bell Telephone Laboratories. While studying for his doctorate he was a research assistant in the Department of Electrical Engineering at M.I.T., and spent one year working on his dissertation at the General Radio Company. He remained at M.I.T. for one year after receiving his degree.

He was employed by General Radio Company in 1936, and subsequently became Assistant Chief Engineer, and Chief Engineer. In 1955 he was appointed Vice-President, and in 1956 was elected a Director. He is also a member of General Radio's Management and New Products Committees, chairman of the Patents and Development Committees, and a trustee of the General Radio Profit-Sharing Trust.

During World War II he was in charge of the search-receiver work for radar countermeasures at the Radio Research Laboratory at Harvard University, and was a member of Division Five of the National Defense Research Committee on guided missiles. In 1943 he went to North Africa with the first *Ferret* plane to be sent to the European theater of operations. For his work on countermeasures and guided missiles he received the President's Certificate of Merit in 1948. From 1954 to 1958 he was a member of the Technical Advisory Panel on Electronics of the Department of Defense.

Dr. Sinclair was President of the IRE in 1952, following a term as Treasurer in 1949–1950. He served on the Executive Committee in 1948–1950 and again in 1952–1953, and was previously on the Board of Directors from 1945 to 1954. He has represented the Institute on the Radio Technical Planning Board, the Joint IRE-AIEE Coordination Committee, and most recently, at the 1958 meeting of the A. S. Popov Society in Moscow.

In the Boston Section he has been a member of the Executive Committee, 1946–1948 and 1952–1958, member and chairman of the Awards Nominating Committee, and chairman of the Program Committee. This latter term of office included the first NEREM meeting in 1947.

He is a Fellow of the American Institute of Electrical Engineers, and a member of Sigma Xi and the American Association for the Advancement of Science.

Scanning the Issue

Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine (Hatsopoulos and Kaye, p. 1574)—One of the most interesting developments now being worked on in any field of engineering concerns a device which by means of thermionic emission will convert heat directly into electrical energy without requiring any moving mechanical parts. This paper describes the construction and operating results of one of the few such thermoelectron engines to be built so far. The word "engine" aptly describes this device because it is a true heat engine in the same sense that a steam power plant is. Heat is supplied to a working fluid at high temperature to produce a gas which performs useful work and gives up heat at a lower temperature. The cycle is completed by pumping the fluid back to the high-temperature end of the system. The working fluid in this case is an electron gas which is boiled out of a hot cathode and passed through a vacuum to a cold anode. Useful work is produced by the passage of the electrons through a retarding field between cathode and anode. The experimental results show an efficiency of over 10 per cent is now attainable and that considerably higher efficiency can be expected in future models.

Sputnik I's Last Days in Orbit (Kraus and Dreese, p. 1580)—Last March the PROCEEDINGS published three letters to the Editor which 1) suggested that certain variations in the observed signal from the transmitter of Sputnik I were due to a bunching of ionized air molecules in front of the onrushing satellite as they rebounded from its nose, 2) reported that this ionization could be detected by reflections of signals from radio stations located on the ground, and 3) by means of reflections of WWV signals, traced the gradual disintegration of Sputnik into a dozen or more pieces. These reports, especially the latter, attracted world-wide attention in the technical and lay press and among many scientific groups engaged in satellite tracking and ionospheric investigations for the IGY, because they offered the only evidence in existence of when and how Sputnik I met its demise. This paper is a complete description and interpretation of the observations reported in brief earlier. The widespread interest in this work is heightened by the fact that a divergence of opinion exists in scientific circles concerning the suitability of the statistical methods and extrapolations which were needed to explain and interpret the results. This in no way detracts from the value of this paper. On the contrary, this paper will provide an exceedingly valuable reference point for further investigation of the ingenious methods proposed by the authors, as well as results which are of importance to all those concerned with the problem of reentry of orbiting objects and with the physics of the upper atmosphere.

Noise in Maser Amplifiers—Theory and Experiment (Gordon and White, p. 1588)—One of the liveliest subjects in radio engineering at this time concerns low-noise microwave amplification. Recent advances in traveling-wave tubes have lowered their noise levels to well below earlier predictions. Meanwhile, parametric-type amplifiers have been developed with even lower noise figures. The lowest of the low, however, is the maser. Its low-noise properties have already been put to important use in the field of radio astronomy to extend substantially the range of radio telescopes. This paper presents an excellent theoretical analysis of noise in maser amplifiers and the results of experimental measurements of the noise of an ammonia beam maser, contributing substantially to our understanding of this important subject.

The Spherical Coil as an Inductor, Shield, or Antenna (Wheeler, p. 1595)—This paper considers a unique form of inductor, a spherical coil, which because of its geometry lends itself to unusually simple and exact mathematical formulations of its magnetic and related characteristics. Since the spherical coil is an idealized rather than a practical form of inductor, these exact results will be of direct interest mainly to teachers and students of field theory, who should find the simplicity of the concepts quite intriguing. However, the results can be useful to the practicing engineer, as well. The principles of coupling, shielding, and the effects of core materials, for example, are reduced to such simple expressions that from them the effects of nonspherical geometries can be readily estimated.

Error Probabilities for Binary Symmetric Ideal Reception Through Nonselective Slow Fading and Noise (Turin, p. 1603)—An excellent study has been made of the effects of fading and noise on the accuracy with which a receiver will guess which of the two known wave shapes was transmitted over a binary data transmission system. The paper, while somewhat specialized, will find quite wide application in the fields of communications systems, information theory, and wave propagation. The author shows, as an example, how his results can be used to determine the effects of pulse shape and frequency separation on the performance of a frequency-shift-key teletype system working through a scatter propagation link.

Diffraction by Smooth Cylindrical Mountains (Neugebauer and Bachynski, p. 1619)—During the Korean War, soldiers in the field found to their surprise that in some cases the presence of a mountain between transmitter and receiver caused better reception than if there had been no obstacle at all. Studies of propagation over the mountainous terrains of Japan, Hawaii, and Alaska confirmed this unexpected result and the phenomenon, known as obstacle gain, was reported in the PROCEEDINGS five years ago. It was recognized that the effect, which occurs at VHF and above, was caused by diffraction of radio waves as they passed over the sharp edge of a mountain. While the principles have thus been well established, the detailed mathematical descriptions of what occurs are at some variance with experimental evidence, enough so as to make it difficult to design accurately a system to take advantage of obstacle gain. This paper presents an interesting combination of geometric-optical theory with corroborative experimental measurements obtained with models of mountains in the laboratory which make an important contribution to the solution of practical engineering problems involving obstacle gain.

Refraction Anomalies in Airborne Propagation (Wong, p. 1628)—Ray tracing techniques are used to explain the irregularities of radio wave propagation caused by various refractive index patterns of the atmosphere, determined from airborne measurements. This is one of the first correlations of refractive index structure and radio signal strength, and opens up a new field of prediction of communication and radar propagation characteristics that will be of wide interest in those fields.

A Cathode Test Utilizing Noise Measurements (Dahlke and Dloughy, p. 1639)—This paper describes a simple and sensitive method for measuring the quality of oxide cathodes by means of shot-noise measurements. The method proposed is a fundamental contribution to tube testing techniques and will probably be widely adopted by manufacturers.

IRE Standards on Definitions of Terms on Information Theory (p. 1646)—This important Standard sets forth the definitions of 34 basic terms relating to measures of information that are central to the field of information theory.

Scanning the Transactions **appears on page 1661.**

Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine*

G. N. HATSOPOULOS† AND J. KAYE†

Summary—The direct conversion of heat into useful electrical work without utilization of moving mechanical parts has been successfully achieved in a novel device called the thermoelectron engine. This device is a heat engine in the thermodynamic sense because the working fluid, an electron gas, receives heat at a high temperature, rejects heat at a lower temperature, and delivers useful electrical work to an external load. This heat engine is also a thermionic device in that the electron gas is produced by emission from a hot cathode in a vacuum and by absorption or condensation of the electrons on a colder anode at a higher negative potential.

The basic principle underlying this heat engine is that a calculable fraction of electrons emitted from a hot cathode possess sufficiently high values of emission velocity to overcome a retarding electrostatic potential barrier between cathode and anode in a vacuum. Thus these electrons can transform their high initial value of kinetic energy into useful potential energy at the colder anode; this potential energy can then be utilized by connecting cathode and anode externally through a matched impedance in the form of a load. Hence, this engine utilizes a selection process which results in a large value of output voltage per unit cell compared with the output of a thermoelectric generator per unit thermocouple.

The important engineering aspects of this successful heat engine comprise, first, the use of emissive surfaces which can be machined carefully to high tolerances and thus permit very small spacing between cathode and anode, of the order of 0.001 inch or less, and secondly, the heat transfer designs which can greatly reduce unnecessary heat losses at the required high temperatures.

A brief analysis of the diode configuration of a thermoelectron engine is given to predict the performance of several models. Out of a total of ten successful models of the diode configuration, the experimental results for one model have been selected for presentation here. A thermal efficiency of between 12 to 13 per cent has been attained based on measured power output and calculated values of heat input. Power outputs of the order of 1 watt/cm² of emissive surface have been measured with this small feasibility model.

If the theory and the presently available data are used as a basis of extrapolation it appears that thermal efficiencies greater than 15 per cent may be attained. The power output might reach values of the order of 10 to 30 watts/cm² of emissive surface. Multiplate designs also indicate the attainability of fairly large values of power output per total volume or per total weight of equipment.

NOMENCLATURE

A = constant in Richardson's (1), amp/(°K² cm²).
J_0 = output current density, amp/cm² of emissive surface*.
J_s = saturation current density, amp/cm² of emissive surface*.
k = Boltzmann's constant, 0.8616×10^{-4} ev/°K.
P_1 = ohmic power loss in external leads, watts/cm²*.
P_0 = power output, watts/cm²*.
q = heat flux, watts/cm²*.
q_c = heat flux by conduction, watts/cm²*.
q_r = heat flux by radiation, watts/cm²*.
T = temperature.
V_0 = output voltage, volt.
ϵ = thermal emissivity of electron emissive surface.
ϕ = work function, volt.
η = thermal efficiency.
σ = Stefan's radiation constant, watts/(°K⁴ cm²)*.

Subscripts

$_0$ refers to output of engine.
$_1$ refers to hot cathode.
$_2$ refers to cold anode.

Superscript

* refers to unit area of emissive surface.

INTRODUCTION

A METHOD for the efficient conversion of heat directly into useful electrical work without the utilization of moving mechanical parts, which shows promise of becoming a practical engineering device, has been successfully tested. The conversion device to be described is the result of a basic research program started about four years ago at M.I.T. in the Research Laboratory of Heat Transfer in Electronics. Several different types of conversion devices have been analyzed and feasibility models have been constructed and tested. All are, in reality, heat engines which employ electrons or an "electron gas" as a working fluid undergoing a cyclic process. These conversion devices, which are based on thermionic emission, are labelled herein "thermoelectron engines" to distinguish them from conversion devices utilizing thermocouples in the form of well-known thermoelectric generators. Although several diverse forms of thermoelectron engines have been analyzed, designed, constructed, and tested, only one particular form, namely the diode configuration, will be described herein.

Briefly, the thermoelectron engine is a true heat engine in the customary thermodynamic sense, and is comparable with the steam power plant as a heat engine. In both heat engines, heat is supplied to a working fluid at high temperature, producing a vapor or gas capable of delivering useful work to the surroundings. Heat is rejected from this working fluid at a lower temperature, and then the fluid completes the cyclic process, being finally pumped to the part of the device supplying heat at the high temperature. In the case of the thermoelectron engine, the working fluid is the electron gas. Initially, this electron gas is in the metallic cathode which is heated to maintain it at a high temperature,

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* Original manuscript received by the IRE, May 1, 1958; revised manuscript received, May 29, 1958.

† Dept. of Mech. Eng., Mass. Inst. Tech., Cambridge, Mass.

T_1. The electron gas is then evaporated or boiled out of the cathode and passed through a vacuum to the colder anode. It is then condensed on the anode which is cooled to maintain it at a lower temperature, T_2. The electron gas delivers useful work to the surroundings as a result of its passage through a retarding electrostatic field in the vacuum between cathode and anode. This useful work is, in fact, the electrical work delivered to the external load.

The use of the Edison effect for the conversion of heat into electric power has often been mentioned in the literature on thermionic devices. Champeix[1] in 1951 gave a qualitative discussion of one such method and concluded that this method was impractical. The first detailed electronic and thermodynamic study on the subject was given by one of the authors in 1956,[2] who analyzed the use of close spacings and of a crossed electric and magnetic field for offsetting the effects of space charge. His diode analysis was based on the approximate Childs-Langmuir equation. Subsequently Moss[3] in 1957 analyzed the diode by means of the exact solution of the Poisson's equation.

OBJECTIVES

The objectives of this report are mainly twofold:

1) An analysis of the diode configuration of a novel thermoelectron engine is given in detail.

2) The experimental results obtained with a feasibility model of the diode configuration are given and discussed briefly.

ANALYSIS OF THE DIODE CONFIGURATION

The analysis of this thermionic device operating as a heat engine is based on the laws of thermodynamics, statistical mechanics, and electrical phenomena, including the results available from quantum mechanics. A brief description of this analysis will be given first to acquaint the reader with the basic assumptions used.

Consider a hot plane cathode opposite to a cold plane anode, each being made from the same emissive material. The distribution of electron velocities and energies inside each metal is assumed given by Fermi-Dirac statistics. As the electrons are evaporated from the hot cathode, at say 2500°F, it is assumed that they have a Maxwellian distribution of velocity and energy in the vacuum just beyond the cathode surface. If a negative retarding potential is supplied to the anode, then a calculable fraction of the emitted electrons possess sufficient kinetic energy to overcome this retarding potential barrier in the vacuum between cathode and anode, including the space-charge barrier formed by the electron cloud just beyond the cathode surface. It is evident that a selection process will then occur, in that not all the emitted electrons will pass through this retarding potential but only those which possess a sufficiently high value of emission velocity normal to the cathode. All those electrons which overcome this retarding potential barrier condense on the colder anode surface, if it is assumed that the reflection coefficient for electrons arriving at the anode is zero; this assumption is not quite true if the quantum-mechanical model of electrons is used.

In addition to the emission of electrons from the hot cathode directed towards the anode, there is also an emission of electrons from the colder anode directed towards the cathode. As in the case of the electrons emitted from the cathode, only a calculable fraction of electrons emitted from the anode will possess a sufficiently high value of emission velocity to overcome the retarding potential barrier from anode to cathode; this barrier is, in general, smaller than that from cathode to anode. Again, it is assumed that the reflection coefficient of electrons reaching the cathode is zero. Hence the net electron flow between cathode and anode is the difference of the two streams described above.

When the cathode and anode are connected by an external circuit through a load, useful electrical work is delivered to this load. In effect, those high-energy electrons which overcome the retarding potential barrier between cathode and anode transform their kinetic energy into useful potential energy at the anode. The output current through the load depends on the temperatures of the cathode and anode, the properties of the emissive materials used, and the spacing between cathode and anode. The thermal efficiency is dependent on these same quantities and also on the heat losses due to radiation and conduction processes.

The analysis of the operation of the diode configuration of the thermoelectron engine is presented briefly.

OUTPUT CURRENT

Consider two parallel plates of emissive material, placed in a vacuum and separated by a distance y, as shown in Fig. 1. For steady-state operation, the cathode is maintained at a temperature, T_1, by a steady input of heat flux, q_1, and the anode is maintained at a lower temperature, T_2, by a steady removal of heat flux, q_2. The potential distribution from cathode to anode is illustrated in Fig. 2, wherein ϕ_1 is the potential barrier for electrons within the cathode relative to its surface, or its work function, δ is the space-charge barrier, ϕ_2 is the work function of the anode, and V_0 is the output voltage obtained when the cathode and anode are connected externally through a load.

The saturation current density of electrons emitted from either cathode or anode in a vacuum is given by the well-known Richardson equation,

$$J_s = AT^2 \exp(-\phi/kT), \tag{1}$$

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[1] M. R. Champeix, "Transformation of heat into electrical energy in thermionic phenomena," *Le Vide*, vol. 6, pp. 936–940; January, 1951.

[2] G. N. Hatsopoulos, "The thermoelectric engine," Sc.D. dissertation, M.I.T., Cambridge, Mass.; May, 1956.

[3] H. Moss, "Thermionic diodes as energy converters," *J. Electronics*, vol. 2, pp. 305–322; January, 1957.

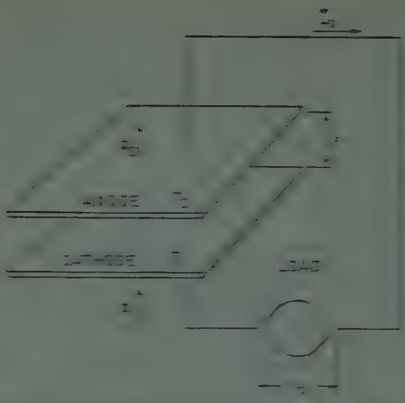

Fig. 1—Thermoelectron engine diode configuration.

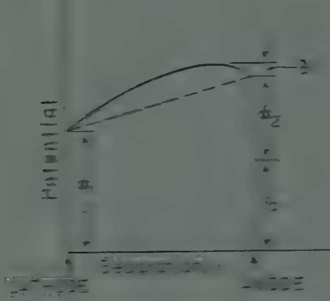

Fig. 2—Schematic representation of potential barrier including space charge.

wherein it is assumed that the surfaces emit electrons uniformly so that considerations based on patch effects are momentarily ignored.

The fraction of the cathode saturation current which reaches the anode is equal to the product of the saturation current and that fraction of emitted electrons which have sufficient initial velocities to overcome the retarding potential barrier of $(\delta+\phi_2+V_0-\phi_1)$; i.e.,

$$\begin{aligned} J_{1\to 2} &= A_1T_1^2 \exp(-\phi_1/kT_1) \\ &\quad\cdot \exp\left[-(\delta+\phi_2+V_0-\phi_1)/kT_1\right] \\ &= A_1T_1^2 \exp(-\phi_2/kT_1)\exp(-\delta/kT_1) \\ &\quad\cdot \exp(-V_0/kT_1). \end{aligned} \tag{2}$$

Likewise, the fraction of the anode saturation current which reaches the cathode is equal to the product of the saturation current and that fraction of emitted electrons which have sufficient initial velocities to overcome the retarding potential barrier equal to δ; i.e.,

$$J_{2\to 1} = A_2T_2^2 \exp(-\phi_2/kT_2)\exp(-\delta/kT_2). \tag{3}$$

Hence the net current density from cathode to anode is given by

$$\begin{aligned} J_0 &\equiv J_{1\to 2} - J_{2\to 1} \\ &= A_1T_1^2 \exp(-\phi_2/kT_1)\exp(-\delta/kT_1)\exp(-V_0/kT_1) \\ &\quad - A_2T_2^2 \exp(-\phi_2/kT_2)\exp(-\delta/kT_2). \end{aligned} \tag{4}$$

The physical significance of (4) is that the net flux of electrons from cathode to anode, or the net current per unit area of emissive surface, depends on the temperatures of cathode and anode, on the space-charge barrier δ, and on the work function of only the cold anode ϕ_2, provided that

$$\delta + \phi_2 + V_0 > \phi_1.$$

The net current density is independent of the work function of the hot cathode; this rather surprising result has been known for a long time for the case of the anode current collected from a hot cathode in a retarding field, when the retarding field is sufficiently great (see Becker[4]). This result has also been verified experimentally by Davisson in 1924.[5]

Analysis of the space-charge barrier shows that its effects could be completely eliminated for practical purposes, for a given value of the net current, and for the case of plane cathode and anode, as in Fig. 1, if the plate separation, y, is made very small, of the order of 0.001 inch. However, the many difficulties of obtaining smooth and uniform emissive surfaces with oxide coatings precluded any practical solution to obtaining such small plate separations. In the last few years, a new engineering emissive material has been developed by the Philips concern in Holland, namely the *L* cathode. This material can be machined to very close tolerances, handled in a rough fashion compared with the delicate and meticulous handling required for oxide coated cathodes, and activated after machining, cleaning, etc., in a fairly straightforward fashion. With this new emissive material we have been successful, after many arduous efforts, in producing engineering models corresponding to Fig. 1, in which plate separations of less than 0.001 inch have been achieved.

If the space-charge barrier, δ, is eliminated from (4), as a result of the use of very small plate separation, and if, as a further approximation, the back current from anode to cathode is made negligibly small by proper selection of T_1 and T_2, then (4) is reduced to

$$J_0 = A_1T_1^2 \exp(-\phi_2/kT_1)\exp(-V_0/kT_1). \tag{5}$$

The power output per unit area of emissive surface is then given by

$$P_0 = J_0V_0 - P_1, \tag{6}$$

where P_1 is the ohmic loss in the external electrical leads per unit area of emissive surface.

THERMAL EFFICIENCY OF DIODE

The thermal efficiency of a true heat engine is defined by the ratio of net power output to total heat supplied and, for this case of a diode configuration, by

$$\eta \equiv (J_0V_0 - P_1)/\sum q_0, \tag{7}$$

---

[4] J. A. Becker, "Thermionic electron emission and absorption, part I, thermionic emission," *Rev. Mod. Phys.*, vol. 7, pp. 95–128; April, 1935.

[5] C. J. Davisson, "The relation between thermionic emission and contact difference of potential," *Phys. Rev.*, vol. 23, p. 299; 1924.

where $\sum q_i$ represents the sum of all heat inputs to the cathode per unit area of emissive surface required to maintain it at temperature, T_1. For the small feasibility model of the diode configuration, which was used to obtain the measured output voltage and current, an accurate measurement of this heat input was most difficult. Hence, the thermal efficiencies given herein are based on measured output voltage and output current and on a calculated value of the heat input to the cathode using the following analysis.

Consider a well-designed engineering model of a multiplate diode configuration of the thermoelectron engine, illustrated schematically in Fig. 3. Such a design can be used as a basis for accurate estimation of the total heat inputs to the hot cathodes. Furthermore, it is evident that such a multiplate design, operating in a vacuum, reduces all unnecessary heat losses to a minimum, since each hot cathode is opposed by two cold anodes. An additional advantage of such a design is that almost any combination of voltages and currents becomes possible by using different ways of electrically connecting cathodes and anodes.

For the engineering model represented by the multiplate design of Fig. 3, the total heat inputs to the cathodes can be given by

$$\sum q_i = J_0\phi_1 + J_0(\phi_2 + V_0 + \delta - \phi_1 + 2kT_1) + q_r + q_c, \quad (8)$$

where $J_0\phi_1$ stands for the heat flux corresponding to the latent heat of evaporation of the electrons from the cathodes;

$$J_0(\phi_2 + V_0 + \delta - \phi_1 + 2kT_1)$$

represents the heat flux corresponding to the kinetic energy of that selected fraction of electrons which can overcome the retarding potential between cathode and anode; q_r represents the thermal radiation flux between each cathode and the pair of adjacent anodes; q_c represents the thermal conduction flux between each cathode and pair of corresponding anodes due to heat conduction along the necessary electrical leads. It should be remembered that the average kinetic energy of all electrons emitted from the cathode surface is $2kT_1$, but only a selected fraction have a kinetic energy sufficient to overcome the retarding potential equal to $(\phi_2 + V_0 + \delta - \phi_1)$.

The thermal radiation flux can be shown, for the geometry of two parallel metallic plates, to be given by

$$q_r = \sigma(T_1^4 - T_2^4)(1/\epsilon_1 + 1/\epsilon_2 - 1)^{-1}, \quad (9)$$

where the emissivities of the cathode, ϵ_1, and of the anode, ϵ_2, are to be evaluated at temperatures, T_1 and $\sqrt{T_1T_2}$, respectively. The geometric mean temperature is used for calculations of ϵ_2 rather than the anode temperature because the metallic surfaces of the cathode and anode are not grey bodies.

The conduction flux can be calculated with the aid of Fourier rule and the geometry of the electrical leads between cathodes and anodes, and the resistivity of these leads. It was found analytically that for maximum efficiency, the cross section of the electrical leads should be selected so that the ohmic loss in these leads equals approximately one-tenth of the thermal conduction losses in the internal electrical leads.

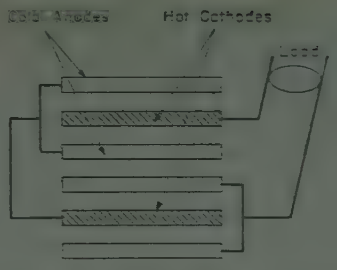

Fig. 3—Multiplate diode configuration of thermoelectron engine.

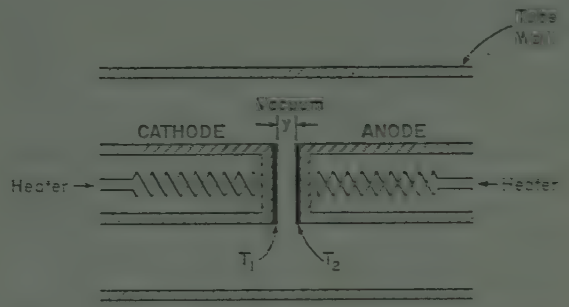

Fig. 4—Details of feasibility model of diode configuration of thermoelectron engine.

EXPERIMENTAL RESULTS

General Description of the Diode

The experimental results presented here are based on the diode configuration described schematically in Fig. 4. Although ten successful models of this configuration have been constructed and tested in this research program, the preliminary data from only one of them will be given here. In this feasibility model, the cathode and anode were hollow molybdenum cylinders about $\frac{1}{2}$ inch in diameter.

The base of each cylinder was impregnated tungsten, and only these bases of the cylinders, facing each other, were used for electron emission and absorption. Each cylinder was fitted carefully with a separate indirect electric heater, wound to eliminate any magnetic fields. The use of indirect electric heaters permitted us to obtain true equipotential cathodes and anodes. Each cylinder could be used interchangeably with the other as cathode or anode, and each could be heated separately to a given steady temperature. Hence the reproducibility of the test results could be examined by simply interchanging the roles of the two cylinders. The cylinders were mounted on supports, which are not indicated in Fig. 4, so that the separation between the emissive surfaces could be varied carefully and accurately during operation of the diode and without breaking the vacuum.

The results given here are based on use of the same emissive material for cathode and anode. This material is made from tungsten which has been impregnated with various combinations of oxides of barium, aluminum, and calcium. The activation process to get this material to emit at high temperatures is fairly straightforward and requires only that it be heated to temperatures higher than those used in the final tests.

The output voltage and current were measured separately. The output voltage was also examined for ac components or ripples with the aid of an oscilloscope, but ac components were not present during the measurements reported here.

The temperature of the surface of the hot cathode was measured with an optical pyrometer which was calibrated against a standard source and which was carefully corrected experimentally for the deviations for nonblack body emission of the molybdenum cylinder by actually bringing both cathode and anode up to the source temperature in a series of auxiliary experiments. The temperature of the surface of the colder anode was usually too low to use this optical pyrometer for an accurate measurement; hence, its surface temperature was estimated in this feasibility model from known values of the thermal emissivities of the cathode and anode and the view factor for radiative transfer between them, including the conduction along the leads. Since the temperature of the colder anode is of secondary importance here, this estimation method sufficed for this model.

The distance of separation of the two plates was measured with the aid of an optical comparator in some of the tests.

The work function of the hot cathode was measured from auxiliary tests on saturation currents; its value was about 1.7 v.

Output Current Density vs Voltage

Fig. 5 shows the experimental results obtained in Run 17B from the feasibility model of the diode configuration. The data indicate that the output current density increases as the potential difference between cathode and anode decreases. Note that this particular model produced a maximum value of current density of about 3 amp/cm².

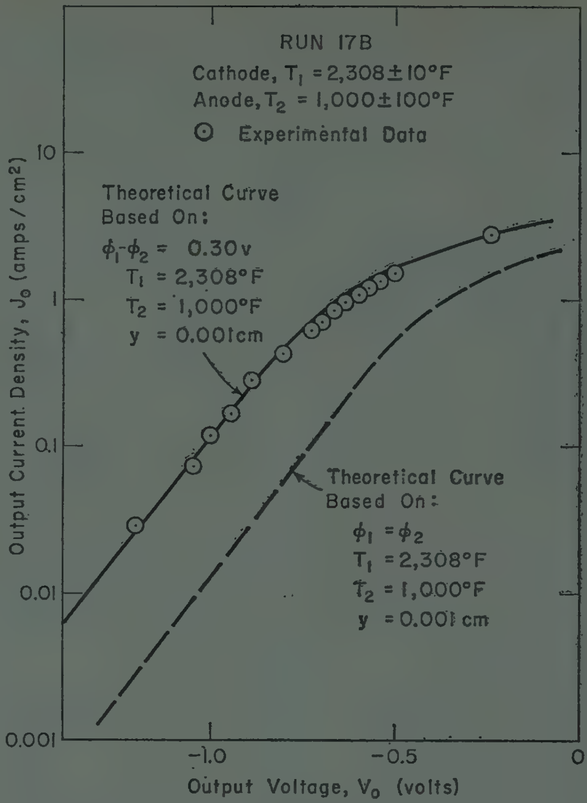

Fig. 5—Comparison of experimental current density with theoretical values for diode configuration.

Fig. 5 also shows two theoretical values of current density. The dashed curve was computed for the measured temperature of the cathode of 2308°F, the estimated value of the anode temperature of 1000°F, for equal values of work function of cathode and anode, and for a value of separation of the two plates, *y*, which was obtained from the tabular values of the solution of the space-charge problem. This solution is found in Kleynen's article.[6] The theoretical dashed curve falls considerably below the experimental points. During the course of testing this model, it was found that the change of work function with temperature of this emissive material could be estimated fairly easily and the results agreed roughly with variations of work function in the literature; see review by Herring and Nichols[7] and Nottingham.[8] Hence these variations were included in the computation of a second theoretical curve, presented by the solid line in Fig. 5.

In this second theoretical prediction of current density, the same values of temperature and of plate separation were used, but the work function of the cold anode was assumed to be less by 0.30 volt. This reduction agreed with both our own estimates and with estimates of change of work function with temperature found in the literature.[7,8] The solid line in Fig. 5 shows excellent agreement with experimental data. Furthermore, the slope of the asymptote of both the solid and dashed curves, *i.e.*, that linear portion extending to high voltages, can be shown to be equal to $(1/kT_1)$. The value of the cathode temperature deduced from this asymptotic slope for the experimental data points agreed with the measured value of T_1 within ±30°F.

Output Power vs Voltage

Fig. 6 shows the experimental results for Run 17B for

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[6] P. H. J. A. Kleynen, "Extension of Langmuir's (ξ, η) tables for a plane diode with a Maxwellian distribution of the electrons," *Philips Res. Reps.*, vol. 1, pp. 79–96; October, 1945.

[7] C. Herring and M. H. Nichols, "Thermionic emission," *Rev. Mod. Phys.*, vol. 21, pp. 185–270; April, 1949.

[8] W. B. Nottingham, "Thermionic Emission," Res. Lab. of Electronics, M.I.T., Cambridge, Mass., Tech. Rep. No. 321; 1956.

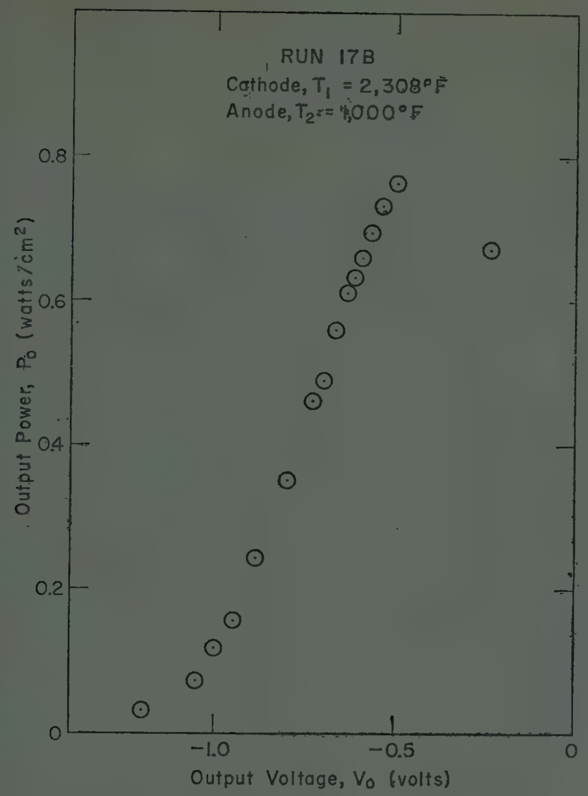

Fig. 6—Experimental power output vs output voltage for diode configuration.

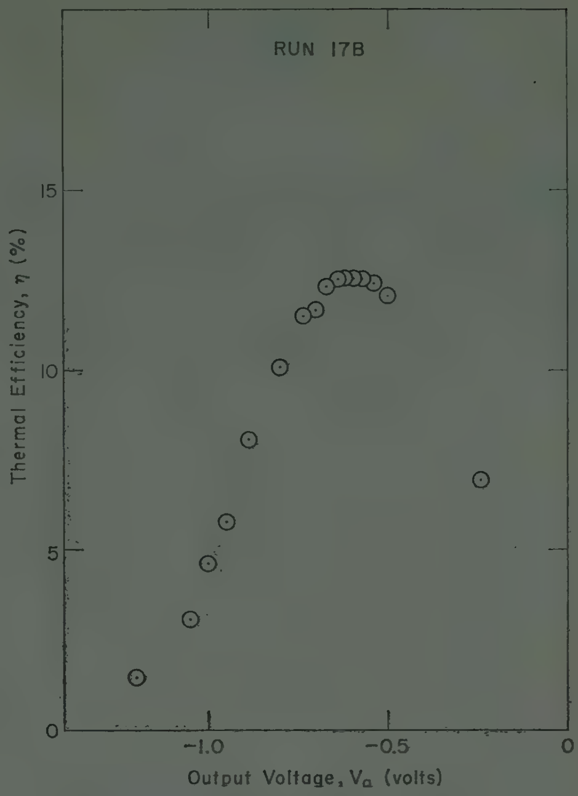

Fig. 7—Experimental results for sample diode configuration of thermoelectron engine.

power output vs voltage for the same temperatures as in Fig. 5. The data indicate a maximum exists for a voltage of about 0.5 volt. The optimum impedance matching of internal and external load characteristics will be discussed later in a separate publication. Likewise the theoretical predictions for comparison with the experimental data are omitted.

Thermal Efficiency vs Voltage

For simplicity of construction of the experimental models tested, there were no provisions made, such as radiation shields and proper geometric design, to reduce the heat input to a minimum. Hence the thermal efficiencies given here were based on the measured voltage and current and on a calculated heat input as explained previously. Fig. 7 shows a typical set of data for thermal efficiency vs output voltage. For this diode configuration a maximum value of thermal efficiency of about 13 per cent was attained for the cathode temperature of 2308°F. Comparison of Figs. 6 and 7 illustrates that the maximum values of thermal efficiency and power output do not occur at the same value of output voltage. Analysis has also shown that the optimum voltage for thermal efficiency does not coincide with the optimum voltage for power output.

Conclusions

The analyses presented herein demonstrate that the behavior of the diode configuration of a thermoelectron engine can be predicted accurately. The experimental results show that an engineering model of such a diode configuration is feasible and that values of the thermal efficiency greater than 10 per cent are now attainable and considerably larger values are predicted for future models.

It is also evident that this diode configuration of the thermoelectron engine can be combined with other presently available power plants to yield a value of thermal efficiency of the combined heat engine which will be considerably greater than 10 per cent.

Acknowledgment

It is indeed a pleasure to acknowledge the helpful discussions with our many colleagues at M.I.T., especially Profs. William P. Allis, Samuel J. Mason, and Stylianos D. Pezaris, and with our colleagues at Thermo Electron Engineering Corporation. We are also grateful for the spirit of the cooperation given us in the past few months by the staff of Thermo Electron Engineering Corporation, especially by John A. Welsh and Gabor Miskolczy.

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Sputnik I's Last Days in Orbit*

J. D. KRAUS†, FELLOW, IRE AND E. E. DREESE†

Summary—Observations during the last days of Sputnik I's orbiting are presented. These observations were made at The Ohio State University Radio Observatory using a simple CW reflection technique. The data suggest that the breakup of an artificial satellite upon its reentry into the denser atmosphere is a complex phenomenon in which a sequential series of events may occur over a period of days. Graphs of the average height of the satellite and its associated fragments as a function of time are presented, and some conclusions are drawn as to the details of the actual breakup phenomenon.

I. Introduction

ARTIFICIAL satellite observations at The Ohio State University Radio Observatory were described which suggested that significant changes in the ionospheric electron density were produced by an artificial satellite[1] and indicated that such changes could be detected by means of a simple CW reflection technique.[2,3] Such a technique is valuable because it makes possible detection of satellites or other objects traversing the ionosphere, without requiring them to have radio transmitters.

It is the purpose of this article to present observational data which appear to be related to passages of Sputnik I and its associated fragments during their last days in orbit. The systematic nature and internal consistency of the data are considered justifications for further analysis involving the drag characteristics of the objects and their rate of fall. Although the results are provisional, they have value as an attempt to reconstruct the events related to the breakup of the first artificial satellite of the earth.

II. The Satellite Ionization Phenomenon

During observations of radio transmissions from Sputnik I early in October, 1957 it was noted that during the satellite's approach the 20-mc signal was very rough and unsteady. However, some time before the satellite reached its closest point of approach, the signal suddenly became very smooth and steady and remained so during the rest of the pass. Oscillographs of the signal before and after the transition and related data have already been presented.[1]

This effect was observed on a number of passes with the transition from rough to smooth signal occurring when the angle between the satellite path and a line from the satellite to Columbus, Ohio was about 60°. The effect was observed only on 20 mc and never on 40 mc. The fact that the phenomenon repeated itself from day to day indicated that it could not be due to the satellite transmitter or antenna. Although ionospheric reflections were considered as a cause, this mechanism seemed unlikely since the effect was observed only while the satellite was approaching and not at all while it was receding. The most plausible explanation was that the phenomenon was caused by an anomalous condition of the medium moving just *ahead* of the satellite.

At an altitude of 100 miles the mean free path of air molecules is of the order of 50 meters, and this path lengthens rapidly with further increase in height.[4] For example, at a height of 200 miles the mean free path is estimated to be as large as 100 kilometers. Under such conditions, when a fast moving object (such as an artificial satellite) encounters a gas particle, it may bounce the particle far ahead in the same manner that a golf ball is driven far ahead by a golf club. If the satellite is travelling with a velocity v and the particle is at rest, the impact can, for a perfectly elastic collision, impart a velocity of $2v$ to the particle directly ahead of the satellite. If the satellite bounces all the particles it encounters directly ahead in this manner, a column of the same cross section as the satellite will be produced ahead of the satellite having twice the ambient density. If the average velocity after impact is less than $2v$, the increase in density would be more than doubled. In the F_2 region, the residual nighttime ionization density may be sufficient (of the order of 3×10^5 electrons per cc) so that a two-fold increase would be significant. However, this is an oversimplified picture. Actually, the particles may be scattered into a cone, instead of bunched in a column, and the particles, if not already ionized, may become so by impact. The satellite's velocity (5 miles per second) is sufficient to ionize air molecules (oxygen and nitrogen in either atomic or molecular form) by impact, although the probability of this mechanism producing ionization appears to be low.

The above discussion is intended to be merely suggestive of a possible ionization mechanism. What constitutes the actual ionization mechanism and whether the ionization is actually ahead of or behind the satellite, or both, are not clear. However, as indicated in Section VIII, some form of ionization phenomenon must be involved.

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* Original manuscript received by the IRE, April 24, 1958.

† Dept. of Elec. Eng., The Ohio State University, Columbus, Ohio.

[1] J. D. Kraus and J. S. Albus, "A note on some signal characteristics of Sputnik I," Proc. IRE, vol. 46, pp. 610–611; March, 1958.

[2] J. D. Kraus, "Detection of Sputnik I and II by CW reflection," Proc. IRE, vol. 46, pp. 611–612; March, 1958.

[3] J. D. Kraus, "The last days of Sputnik I," Proc. IRE, vol. 46, pp. 612–614; March, 1958.

[4] R. J. Havens, R. T. Koll, and H. E. LaGow, "The pressure density and temperature of the earth's atmosphere to 160 km," *J. Geophys. Res.*, vol. 57, pp. 59–72; March, 1952.

III. CW Reflection Method

To determine if this ionization could be detected by reflection, the method of Wylie and Castillo[9] was tried. In accordance with this method, the receiver was tuned to the 20-mc transmission of the National Bureau of Standards time service station WWV near Washington, D. C., a distance of about 330 miles from Columbus, Ohio. During the day ionospheric ionization is sufficient to reflect a strong signal from Washington to Columbus on this frequency, but during the winter night, in particular between local midnight and 7 A.M., the ionization decreases to the point where the signal is either undetectable or extremely weak. Under these conditions, any temporary localized increase in ionospheric ionization may result in a detectable burst in signal. Meteors produce brief signal bursts, the signal being reflected by the temporary ion trails. A meteor-induced signal burst is usually only a few seconds long and only rarely (once or twice per night) more than 10 or 15 seconds in duration. In our experiment at The Ohio State University Radio Observatory, more sustained signal bursts were also detected at times corresponding closely with the latitude crossing times for Sputniks I and II. These signal bursts often lasted for one or more minutes. Sample records of such signal bursts have already been presented in the illustrations of Kraus.[2,3]

The receiving antenna has a maximum response in a vertical east and west plane through Columbus along the 40th parallel of latitude, and the signal bursts produced by a satellite or orbiting object appear to occur, in general, within about two minutes of a latitude crossing of the object. This is convenient, since successive latitude passes of a satellite differ in time by its average period or an integral multiple thereof. Because of the broad east-west response of the antenna, a signal burst from a particular satellite object was obtained nearly every day and on some days two successive passes of the same object were recorded. The antenna consists of two horizontal half-wave dipoles separated on an east-west base line by 350 feet, as already described.[1] Each dipole is oriented north-south.

The basic observational data are presented in Fig. 1. Date is plotted as ordinate and time of day as abscissa. The small circles indicate the time of occurrence of large sustained signal bursts of WWV 20-mc signal on a given date. The area of the circle is approximately proportional to the area under the burst deflection, this area being a convenient criterion for the burst intensity. Only bursts of about 15 seconds duration or longer are shown on the chart. The circles indicate *every* large sustained signal burst satisfying this requirement which was observed during the time covered by the graph, that is, between 0220 and 0620 from December 30 to January 16, inclusive. Examples of actual records covering portions of the chart have already been presented.[2]

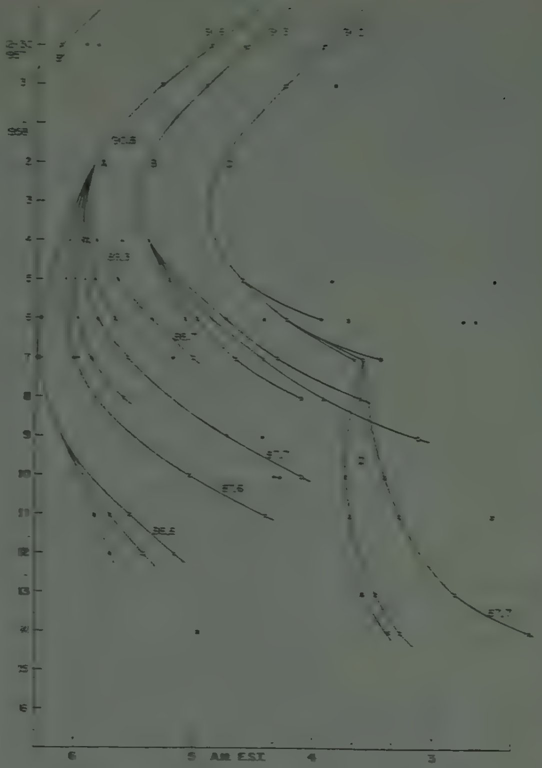

Fig. 1—Observed bursts of WWV signal as a function of date (vertical axis) and time of day (horizontal axis).

If all the circles in Fig. 1 were produced by a random phenomenon, such as natural meteors, there would be little tendency toward systematic trends in their positions. However, if the signal bursts were due to orbiting objects, the circles should show a systematic trend. It is significant that most of the bursts in Fig. 1 show a definite systematic trend.

Referring to December 30 on curve A in Fig. 1, there was a large signal burst at 0452. On December 31 a large signal burst occurred 24 minutes later, or at 0516. The total elapsed time between the two signal bursts was 1464 minutes, or the number of minutes in one solar day (1440) plus 24 minutes. If both bursts were made by the same orbiting object, it must have made an integral number of revolutions (in this case 16) during the 1464-minute interval. Hence, its average period, or time for one revolution, was 91.5 minutes (1464/16). Extending the curve to circles corresponding to passages on following days, it is possible to keep track of the progress of an orbiting object in the absence of any other information.

Of course, to identify the curve with any particular earth satellite, such as Sputnik I, it is necessary at some point of the study to know the approximate period and orbital position of the satellite. On dates in December, earlier than those shown in Fig. 1, curve A was tentatively identified with the spherical part of

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[9] L. R. Wylie and R. T. Castillo, "Clustering of meteors as detected by the use of radio technique," *Ohio J. Science*, vol. 56, pp. 339–347; November, 1956.

Sputnik I with whip antennas (designated 1957α2 by the Smithsonian Astrophysical Observatory).

As a satellite falls closer to the earth, its period decreases. This decrease in period appears on the chart of Fig. 1 as a change in the slope of the curve. For example, a positive slope corresponds to a period of more than 90 minutes, a negative slope to a period of less than 90 minutes, and a vertical slope to a period of exactly 90 minutes. (Note that $16 \times 90 = 1440$ minutes.) The 3-digit figures adjacent to the curves in Fig. 1 indicate the period in minutes at that point of the curve. The absence of data for the first three days of January resulted from an interruption in the observations.[3]

By extending curve A from day to day the progress of the satellite was followed in this manner. Connecting the other signal burst circles on the chart yields two other curves, B and C, which follow a trend very similar to that of curve A, suggesting that they also correspond to parts of Sputnik I. For example, object B may have been the nose cone or part of it.

Although only one signal burst had been anticipated for curve A on January 4, three large bursts were noted. (Actually, more were noted but to simplify the following discussion attention will be confined to the three largest ones. In Fig. 1, the three signal bursts correspond to the circles joined by the three earliest or right-hand curves of the A group.) On January 5 and 6 the three signal bursts again appeared, but showed a significant tendency to spread out in time. The early burst moved farther ahead while the late burst dropped farther behind. This is precisely what would be expected to happen to three satellite bodies of slightly different density and drag, the one with most drag getting farther ahead each day and the one with least drag lagging farther behind. Thus, on January 6, the first and third objects were 27 minutes apart, or separated by about 8000 miles along the satellite's orbit. On January 7 the middle (second) object disappeared, and on January 8 the first object was gone. Although the third object was not noted on January 8, it was observed on January 9 and 10.

It would appear that the A object broke into no less than six distinct pieces, each of which could be detected as an orbiting object for several days. The progress of the slowest moving object of the entire A group is shown by the curve farthest to the left in Fig. 1. Since it was in the highest orbit (longest period), it should have stayed up longest, and this is what was observed to happen. On January 9 or 10 it broke into three smaller fragments which were last observed orbiting on January 12, one day after the next slowest object of the entire A group was last observed. Extrapolating the six group A curves back to dates prior to January 4, it appears that the original A object began to break into pieces between January 1 and 3.

Curves B and C follow a similar trend in slope, but show a generally more rapid decrease in period as would be expected for objects running farther ahead (and lower) in their orbits. Between January 3 and 5 curve B branches into four curves, suggesting a breaking up of the B object between those dates into at least four distinct fragments. The fact that the B fragments show less spread in period than the A fragments would indicate that the B object fragments formed a more homogeneous group.

Referring to curve C, this object appears to have divided on about January 6 into three parts which were last observed on January 7. For a number of days thereafter it was thought that these objects had disappeared entirely, since no bursts were noted which would form a continuation of curve C. However, from January 10–14, at least eight bursts were observed, including one at 0213 (a few minutes ahead of the chart limit) which can be connected in a systematic manner by the curves D. If these curves are significant, they are evidence of an explosion of the C object on or about January 7 into a number of fragments, two of which were raised into a higher orbit where they continued to orbit around the earth until about January 14. The fact that the bursts for the D objects were not observed every day suggests that they were small in size and were observed only on passes with the most favorable signal path geometry. It is also significant that if either object was observed on a given date both were observed. The only other explanation of the D curves is that they are distinctly different objects, not related to the C group, which were noted for the first time on January 10. However, if this were the case, it is difficult to explain why the objects were not observed on earlier dates, the area on the chart where they should have appeared being nearly devoid of signal bursts.

Since all the objects in Fig. 1 had periods between about 87.3 and 91.6 minutes, the question may arise as to why only a single pass of these objects was observed on dates following January 4, whereas two successive passes of the A and B objects had been noted in December (curve B′ in Fig. 1). One explanation is that in December the average height of the objects was sufficient to enable their latitude crossings to be observed farther to the east and west of Columbus than was the case later in January, when the heights were appreciably less and decreasing rapidly. The objects were presumably near their average height when passing near Ohio during this period (travelling NNW to SSE) rather than near the perigee or apogee values. That single passes were observed in January is evident from the observations which show that on any given date no burst pairs, with only one or two exceptions, were separated by the proper period. In addition, since signal bursts from the curve C object were not confused with those from the A object, the 40th parallel crossing of the C object orbit must have been some distance west of that for the A object orbit.

IV. Statistical Considerations

Referring to the hypothetical date-time diagram shown in Fig. 2, there are four dates with the time scale

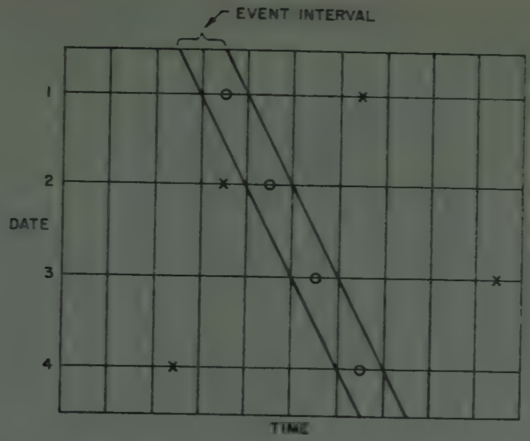

Fig. 2—Date-time diagram for discussion of probability of occurrence of systematically related events.

divided into ten equal intervals. The probability that a single random event will occur in any particular time interval is one in ten. The probability of two events, one on each date, occurring in specified time intervals is one in one hundred. Hence, the probability that the events indicated by the four circles would appear in the designated event interval on four days is only one in ten thousand. Stated in another way, a typical random distribution of four events (one per day) might be as suggested by the crosses in Fig. 2, while the distribution given by the circles would occur on a purely chance or random basis only once in ten thousand four-day intervals. An orbiting object, whose period is decreasing a certain fraction of a minute per day, must follow a definite trend like the event interval in Fig. 2, and any deviations of the observed times of passage amounting to more than a few minutes will obviously not fit such a systematic trend. Applying this type of analysis to the circles of Fig. 1, it follows that the probability of the observed systematic pattern resulting from a random phenomenon is extremely small.

Another important consideration is the self-consistency of the data. This is even more evident from the discussion in later sections of the heights of the objects as a function of time. All of the objects have a generally downward trend in height, with the only abrupt changes in slope occurring at the time of breakups as would be expected. Furthermore, the height data of December 30 and after are entirely consistent with those obtained from other sources for earlier dates (see Fig. 5). Lastly, the fragments were observed only down to heights at which complete disintegration would be expected to occur and no lower.

Another aspect of the data of Fig. 1 concerns the number of bursts observed per night (four-hour period from 0220 to 0620) as a function of date. These data are presented in Fig. 3. Prior to January 5, the number ranged between four and nine bursts, but on January 6 the number reached a peak of 15 bursts during the four-hour period. January 6 was after the breakup of both the A and B objects. After January 6 the number decreased as the objects tended to disappear. However, a small secondary peak appeared on January 10 and 11 following the detection of the D objects and the fragmentation of the slowest A object. After this the number again decreased until January 15 and 16, when no signal bursts whatever were detected during the four-hour period. On January 17–19, an average of only one signal burst per night was observed.

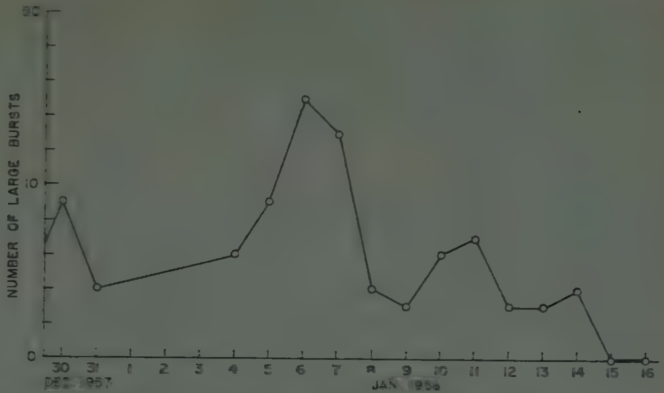

Fig. 3—Graph of number of signal bursts observed as a function of date.

Altogether there are 85 signal bursts on Fig. 1, of which at least 66 follow a systematic pattern. The remainder may be meteor-induced signal bursts of unusually long duration. Over the entire period, December 30 to January 16, they averaged only 1.3 per night. During the remainder of January, the number of large sustained bursts was found to average about 1.5 per night (four-hour period from 0220 to 0620). These bursts appeared to have a random time distribution and, hence, probably were of meteoric origin. Accordingly, the background level of large sustained meteor-induced bursts would appear to average about 1.4 per night, thus suggesting that the large increases in bursts observed over many days in late December and early January were not due to meteors, but to artificial satellites as already considered.

Although the general trends in Fig. 1 may be significant, too much importance should not be attached to an individual branch curve with only one or two signal bursts. Actually, several branch curves in addition to those shown could have been added to single bursts which were treated as random in the above discussion.

V. Average Height Calculations

The data of Fig. 1 become even more significant if converted into a height-time diagram. The slope of any curve in Fig. 1 is a measure of the period of the orbiting object at that time. When the period is known, the height of the object can be calculated from Kepler's third law.[6] Thus, for a circular orbit, the square of the period T of a small object orbiting around the earth is given by

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[6] C. A. Young, "General Astronomy," Ginn and Co., Boston, Mass., pp. 252–255; 1895.

$$T^2 = \frac{4\pi^2}{g} \frac{5280}{3600} \frac{(r+h)^3}{r^2} \tag{1}$$

where

T = period (min)

g = acceleration of gravity at surface of earth (32.1 ft second^{-2})

r = average earth radius (= 3959 statute miles)[7]

h = average height of object (statute miles).

Evaluating (1) for various values of T (or h) a large scale period-height chart was prepared. Then, from the period of a given object as determined from Fig. 1, its average height could be obtained. Actually, the average period for a given object over a one-day interval was used in this conversion, and was found by dividing the total elapsed time between bursts on succeeding days by 16.

The actual orbit of a satellite is elliptical with a point of near approach (perigee) and a most distant point (apogee) which may differ considerably from the average height. However, average height (equal to half the sum of the perigee and apogee heights) is a significant quantity which makes it possible to discuss the trends in height as a function of time in a simple manner. The height values calculated are good approximations of the average height and are sufficient for this discussion of the height vs time behavior of satellites and their associated fragments.

VI. Height Data

The height data, obtained as described above, are presented in Fig. 4. The average height (in miles or kilometers) is given as a function of date for the A, B, and C objects and their fragments. The A group is shown by the solid lines, the B group by the dashed lines, and the C (and also D) group by the dotted lines. Each group exhibits a slightly different behavior which presumably reflects a difference in its drag characteristics. The original object of the A group has the greatest initial height, and after breakup the fragments have the largest dispersion in heights. This group presumably corresponds to the 23-inch diameter, 184-pound spherical antenna-equipped satellite, with the large height dispersion after breakup being due to the wide range of composition of its constituent parts. The original object of the B group has a somewhat lower initial height, and after breakup its fragments show not only less spread in height, but a tendency to fall more rapidly than the A objects. This suggests among other things that the B fragments were of a more homogeneous nature than those of the A group. The original C object had the lowest initial height, and after breakup its fragments (except for those of the D group) tended to come down much more rapidly. The initial breakup of the A object occurred between January 1 and 3, of the B object between January 3 and 5, and of the C object between January 5 and 6. The D group appears to have consisted of two quite similar objects which were raised into a higher orbit about January 7 by an explosion of one of the C objects. The two D objects are the last orbiting objects observed which appear to have been associated with Sputnik I.

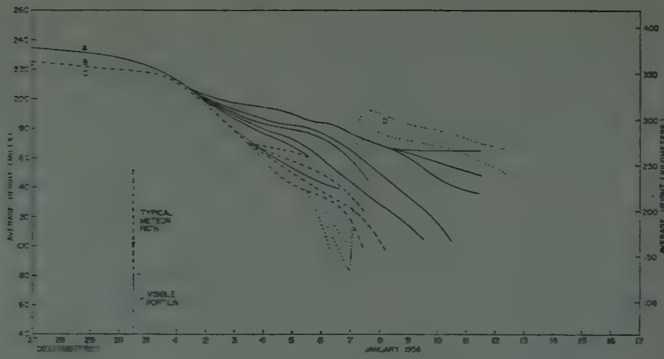

Fig. 4—Average height of Sputnik I objects as function of time as deduced from the signal-burst observations.

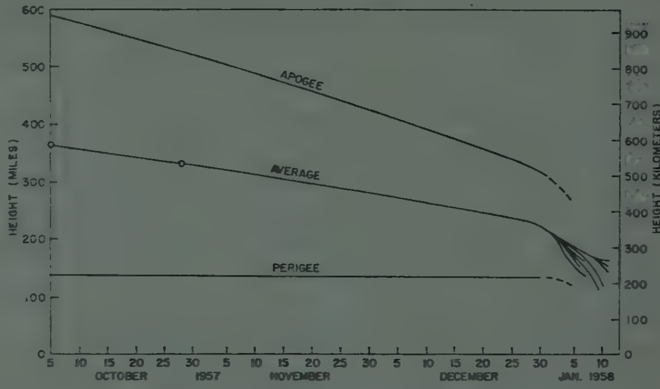

Fig. 5—Average height of Sputnik I during its time in orbit with approximate apogee and perigee heights.

The height variation of object A (presumably the spherical part of Sputnik I) over its entire time in orbit is presented in Fig. 5. The data for A from Fig. 4 appear in Fig. 5 for the dates following December 30 as the average height curve (with branches). The period at the time of launching was 96.2 minutes, giving an initial average height of 365 miles (note circle at left edge of chart). The height circle for October 28 is based on orbital periods given by the Royal Aircraft Establishment, Farnborough.[8] The fact that the height data for December 30 and thereafter, and those for launching and October 28 all join on a smooth curve supports the other evidence that object A corresponds to the spherical antenna-equipped part of Sputnik I. Curves for apogee and perigee heights are also presented in Fig. 5, but these are intended more to suggest trends than to give precise values. They are based mainly on the values announced soon after the satellite was launched.

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[7] The statute mile (5280 feet) is meant wherever the unit mile is mentioned in this article.

[8] Staff of the Royal Aircraft Establishment, Farnborough, Eng., "Observations of the orbit of the first Russian earth satellite," *Nature*, vol. 180, pp. 937–941; November 9, 1957.

VII. Drag and Heating Effects

One of the most interesting aspects of the data presented concerns its interpretation in terms of the drag of the objects and the mechanism of the actual breakup process. This has great significance in connection with the problem of the reentry of an orbiting object into the denser regions of the earth's atmosphere.[9–13]

An artificial satellite will, in general, have an elliptical orbit. At apogee the satellite may be well outside the denser parts of the earth's atmosphere, but at perigee it may dip close enough to the earth to encounter considerable resistance from the earth's atmosphere. Energy lost by drag at perigee will not affect the perigee height but will result in a decrease in the apogee height. Conversely, drag encountered at apogee will result in a reduced perigee height. Since initially the drag occurs principally at perigee, the effect is to reduce the eccentricity of the orbit by a reduction in the apogee height. This situation is illustrated by the idealized orbits in Fig. 6 with three satellite orbits shown of different apogee but constant perigee height. For convenience, the denser part of the earth's atmosphere is shown with a definite upper edge instead of the actual diffuse limit. The height of the atmosphere and of the orbits is exaggerated for the sake of clarity.

Meteors enter the earth's atmosphere at very high velocities (7 to 45 miles per second) heating up to incandescence by the time they reach heights of 45 to 80 miles above the earth's surface.[14] However, the process is usually of very short duration, lasting only for a few seconds. This is because most meteors enter the atmosphere at angles steeper than tangency. A typical meteor path is shown in Figs. 6 and 4. Because of the long time scale of Fig. 4 a meteor, even of many seconds duration, will appear as a vertical line.

In contrast the satellite objects enter the earth's atmosphere nearly tangent to its surface, but remain in it for relatively long periods (hundreds or thousands of seconds). The resulting heating at each perigee passage may, accordingly, produce significant effects at perigee heights well above that at which the meteors reach incandescence in their brief flight through the atmosphere. In fact, satellite objects with eccentric orbits are subjected to a cyclical heating process which may cause metal fatigue and cracking long before melting temperatures are reached.

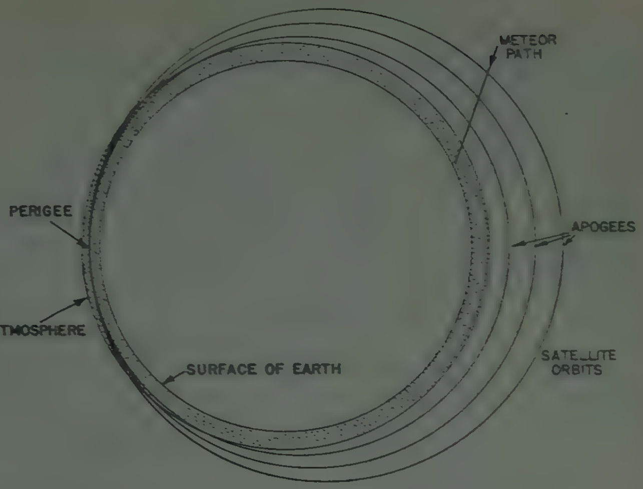

Fig. 6—Diagram illustrating decrease of apogee height of satellite orbit with substantially constant perigee height.

If the satellite were a solid homogeneous metal sphere, the heating might produce little destructive effect until carried to extremes. However, consider for the purpose of discussion two solid homogeneous metal spheres connected by a thin member, as in Fig. 7. As this object moves broadside through the atmosphere, its surface will be heated. Since, however, the thermal capacity of the thin member is less than that of the solid spheres, its temperature will rise faster than the temperature of the spheres. Conversely, in a cooling portion of the temperature cycle (after leaving perigee), the temperature of the thin member will fall faster than the temperature of the spheres. Hence the temperature fluctuations will be greater for the thin member. As the orbit descends, the heating will increase and the thin member will reach destructive temperatures first and the object will separate into two portions. Since the Sputnik I sphere was a complex object fabricated from many parts of different density, it is reasonable to suppose that (with the metal skin removed) the framework holding the heavy and denser components together may have separated at its thinnest and weakest points by a similar process resulting in a breakup into many pieces. The pieces with large drag would fall rapidly, but the more massive objects of lower drag might continue in orbit for somewhat longer.

Specifically, *drag* is a force opposite to the direction of motion of the object.[15] It is proportional to the cross

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[9] J. P. Hagen, "The exploration of outer space with an earth satellite," Proc. IRE, vol. 44, pp. 744–747; June, 1956.

[10] J. T. Mengel, "Tracking the earth satellite, and data transmission, by radio," Proc. IRE, vol. 44, pp. 755–760; June, 1956.

[11] F. L. Whipple and J. A. Hynek, "A research program based on the optical tracking of artificial earth satellites," Proc. IRE, vol. 44, pp. 760–764; June, 1956.

[12] J. A. Van Allen, "The scientific value of the earth satellite program," Proc. IRE, vol. 44, pp. 764–767; June, 1956.

[13] T. E. Sterne, B. M. Folkart, and G. F. Schilling, "An Interim Model Atmosphere Fitted to Preliminary Densities Inferred from U.S.S.R. Satellites," Smithsonian Institution Astrophysical Observatory, Cambridge, Mass., Special Rep. No. 7; December 31, 1957.

[14] B. Lovell and J. A. Clegg, "Radio Astronomy," John Wiley and Sons, Inc., New York, N. Y., p. 76; 1952.

[15] L. M. Milne-Thomson, "Theoretical Aerodynamics," MacMillan and Co., Ltd., London, Eng., p. 3; 1948.

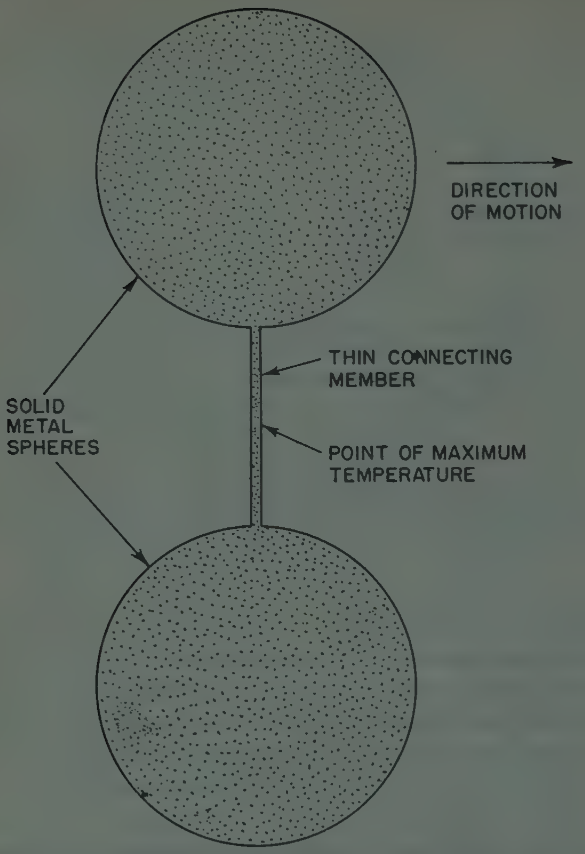

Fig. 7—Thin member connecting two solid spheres will melt first as assembly is heated by motion through the air.

sectional area of the object normal to its direction of motion. It follows that the drag force per unit mass is equal to the negative acceleration or deceleration of the object, and further, that the energy lost by a satellite object due to drag per orbital period is given by

$$W = \oint D dl \qquad (2)$$

where

W = energy lost in one period (joules)
D = drag (newtons)
dl = elemental length along orbit (m).

The integration is carried out once around the orbit.

Of particular interest in interpreting Fig. 4, it may be shown that at a given average height, the rate of change of average height of an orbiting object is proportional to its average drag per unit mass. Hence, at a given height the objects with steeper slope have higher drag per unit mass than those with smaller (or flatter) slope. Actually, over the range of heights involved, the slope at any height is a good approximation to the drag per unit mass. Several special cases may be considered.

1) A hollow shell containing an assembly of massive or high density parts would, in general, have higher drag per unit mass than the individual high density components after separation. Since most of the A group fragments had less drag per unit mass than the original A object, it is likely that these fragments were some of the higher density components (such as batteries). It is significant that the object with the least drag per unit mass or its three fragments remained in orbit longest (until January 12). (Although the uppermost curve for the three fragments may appear to have a positive slope, it is actually negative.)

2) The fragments of a homogeneous object will, in general, have higher drag per unit mass than the original object. This would appear to be the case for the C group after breakup about January 6.

3) The fragments of a nonhomogeneous object will, in general, have both higher and lower drag per unit mass than for the original object. Although both the A and B objects were presumably nonhomogeneous, only one fragment of each showed more drag per unit mass than the original object, the remaining fragments having less. This may be explained by the fact that an object with high drag per unit mass falls faster, and unless it remained in orbit for at least one day after the breakup it would not be detectable at all by the method used.

It should be mentioned that although the general trends in Figs. 1 and 4 are significant, too much importance should not be attached to objects for which burst data were observed on only one or two days. To insure a high probability that the bursts corresponded to an orbiting object, it is desirable to have burst data for at least three days.

No direct evidence is available of the ultimate fate of the satellite fragments, but it is likely that as a result of the gradual disintegration process, some very small or dust size particles may have been produced which remained up for some time after all the larger fragments had fallen. It is possible that this residual dust was distributed completely around the orbit in a manner analogous to the distribution of debris in a comet's orbit, forming the material of a meteor stream.

Although no reports were received which gave conclusive evidence of visual sightings of any Sputnik I fragments falling to the ground, a number of observers in the vicinity of Columbus, Ohio did report a bright self-luminous orange-red object moving in horizontal flight from NW to SE across the sky to the NE of Columbus about two hours before sunrise on the morning of January 4. As already reported,[8] this object was on the Sputnik I course and was observed at 0555, or at the same time as the January 4 signal burst marked with an X in Fig. 1. The object was observed for at least 15 seconds and was described by various observers as trailing a thin short streak a few degrees long as though shedding incandescent particles. Its color was described as bright yellow or orange-red when first seen to the north and changing to a dark red as it disappeared to the east. It is possible that this object was a Sputnik I group A object and, when seen, sharp edges were burning off or connecting members burning apart with visible effect during the object's dip into the lower atmosphere. However, the main body of the object may have continued to orbit for some time longer.

VIII. Echo Area

In connection with the CW reflection method it is of interest to calculate the order of magnitude of extent of the ionospheric reflecting surface required to give the strengths of WWV signal bursts observed at Columbus, Ohio. This may be done by assuming that the path consists of two parts, one from the transmitter near Washington, D. C. to the point of reflection in the ionosphere, and the other from this reflection point to Columbus, Ohio. It will be assumed that at the reflection point the signal from Washington is gathered over an effective aperture A_e and then retransmitted without loss or gain to Columbus through an aperture of the same effective size. Applying the Friis transmission formula[16] twice to this two-link circuit yields the following value for the square of the effective aperture of the ionospheric reflecting region:

$$A_e^2 = r^4\lambda^4 \frac{W_r}{W_t A_{et} A_{er}} \tag{3}$$

where

A_e = effective aperture of ionospheric reflection region (m^2)
r = distance from point of reflection to Washington or Columbus (m)
λ = wavelength (m)
W_t = transmitter radiated power (watts)
W_r = received power (watts)
A_{et} = effective aperture of transmitting antenna (m^2)
A_{er} = effective aperture of receiving antenna (m^2).

For the case under consideration, $r = 365$ kilometers, $\lambda = 15$ meters, $W_t = 10^3$ watts, $W_r = 2.5 \times 10^{-15}$ watts (corresponding to 0.1 microvolt per meter at the antenna), $A_{et} = 0.25\lambda^2(\text{m}^2)$, and $A_{er} = 0.5\lambda^2(\text{m}^2)$. Introducing these values into (3) gives an effective aperture A_e of the ionospheric reflecting region of about 600 square meters. This area is nearly a minimum value, and for less favorable path geometry or other factors the aperture would be larger, suggesting that some ionization phenomenon must be involved.

Acknowledgment

We are indebted to George Veis of the Institute of Geodesy for helpful comments and to James S. Albus of the Department of Electrical Engineering for assistance on some of the observations during the latter part of January.

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[16] J. D. Kraus, "Antennas," McGraw-Hill Book Co., Inc., New York, N. Y., p. 54; 1950.

CORRECTION

Stig Ekelöf has sent in the following correction to a paper by Frank E. Jaumot, "Thermoelectric Effects," which appeared on pages 538–544 of the March, 1958 issue of Proceedings. The Ph.D. Dissertation by D. Enskog, referred to in footnote 18, was published at Uppsala University, Sweden, not at Upsala College, East Orange, N. J.

Noise in Maser Amplifiers—Theory and Experiment*

J. P. GORDON† AND L. D. WHITE†, MEMBER, IRE

Summary—**This paper contains a theoretical treatment of noise in maser amplifiers and the results of experimental measurements of the noise of an ammonia beam maser. The concept of "effective input noise temperature" is defined and used. The theoretical treatment obtains an equivalent microwave circuit and derives expressions for the gain and effective input noise temperature of both reflection and transmission-type masers. The experimental measurements yielded values of about 80°K for the effective input noise temperature of a reflection-type ammonia beam maser. The experimental values agree with those predicted by theory and the comparison of experiment and theory gives an upper limit of about 20°K for the magnitude of the "beam temperature."**

INTRODUCTION

It has been realized for some time that maser amplifiers should be capable of very low noise operation.[1] Recently, several papers have given theoretical calculations[2–6] of the noise generated by "negative temperature" media, and predictions[3–7] of the noise figures of maser amplifiers. Also quite recently, experimental measurements of the noise figures of ammonia maser amplifiers[8–10] and of a solid-state maser amplifier[11] have been made. This paper reviews the theory of maser amplifiers, using an equivalent microwave circuit. This theory applies to two-level masers and also to three-level types in which noise introduced by the pumping source can be ignored. The term "effective input noise temperature"[12] is defined. This term is quite useful in describing very low noise amplifiers and gives a more immediate idea of the quality of the amplifier than does the usual description in terms of noise figure. Experimental values for the effective input noise temperature of an ammonia maser are given and are compared with those obtained from theory. From this comparison an upper limit for the beam temperature is obtained.

EFFECTIVE INPUT NOISE TEMPERATURE

The "effective input noise temperature,"[12] $T_n(f)$, is defined here as the temperature of the input termination which results at frequency f in output noise power per unit bandwidth double that which would occur if the same input termination were at absolute zero. The effective noise temperature is related to the noise figure $F(f)$ of the amplifier with the same input by $T_n(f) = [F(f) - 1]$ 290°K. The average effective input noise temperature $\overline{T}_n$ is defined as the temperature of the input termination which results in a total noise power output double that which would exist if the same input termination were at absolute zero. The average effective input noise temperature is related to the spot effective input noise temperature by

$$\overline{T}_n = \frac{\int T_n(f)G(f)d_j}{\int G(f)df}$$

where $G(f)$ is the power gain of the amplifier. Also, $\overline{T}_n = [\overline{F} - 1]$ 290°K, where $\overline{F}$ is the average noise figure. This concept of effective input noise temperature becomes particularly valuable in applications in which both the effective input noise temperature of the amplifier and the noise temperature of the input load (*e.g.*, an antenna looking at the sky) are less than room temperature.

For convenience, it is assumed in the following that the input termination is matched to the input waveguide.

THEORY OF NOISE IN A CAVITY MASER AMPLIFIER

In this section the noise output of a cavity maser amplifier is considered in detail, using the approach of the microwave circuit. The sources of noise include the

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* Original manuscript received by the IRE, April 3, 1958; revised manuscript received, May 27, 1958.

† Bell Telephone Labs., Inc., Murray Hill, N. J.

[1] J. P. Gordon, H. J. Zeiger, and C. H. Townes, "Molecular microwave oscillator and new hyperfine structure in the microwave spectrum of NH_3," *Phys. Rev.* vol. 95, pp. 282–284; July 1, 1954.
———, "The maser—new type of microwave amplifier, frequency standard, and spectrometer," *Phys. Rev.*, vol. 99, pp. 1264–1274; August 15, 1955.

[2] K. Shimoda, H. Takahasi, and C. H. Townes, "Fluctuations in amplification of quanta with application of maser amplifiers," *J. Phys. Soc., Japan*, vol. 12, pp. 686–700; June, 1957.

[3] J. P. Wittke, "Molecular amplification and generation of microwaves," PROC. IRE, vol. 45, pp. 291–316; March, 1957.

[4] R. V. Pound, "Spontaneous emission and the noise figure of maser amplifiers," *Ann. Phys.*, vol. 1, pp. 24–32; April, 1957.

[5] M. W. Muller, "Noise in a molecular amplifier," *Phys. Rev.*, vol. 106, pp. 8–12; April 1, 1957.

[6] M. W. P. Strandberg, "Inherent noise of quantum-mechanical amplifiers," *Phys. Rev.*, vol. 106, pp. 617–620; May 15, 1957.

[7] J. C. Helmer and M. W. Muller, to be published.

[8] J. C. Helmer, "Maser noise measurement," *Phys. Rev.*, vol. 107, p. 902; August 1, 1957.

[9] L. E. Alsop, J. A. Giordmaine, C. H. Townes, and T. C. Wang, "Measurement of noise in a maser amplifier," *Phys. Rev.*, vol. 107, pp. 1450–1451; September 1, 1957.

[10] J. P. Gordon and L. D. White, "Experimental determination of the noise figure of an ammonia maser," *Phys. Rev.*, vol. 107, pp. 1728–1729; September 15, 1957.

[11] A. L. McWhorter, J. W. Meyer, and P. D. Strum, "Noise temperature measurement on a solid state maser," *Phys. Rev.*, vol. 108, pp. 1642–1644; December 15, 1957.

[12] The wording "effective input noise temperature" was chosen after consultation with H. A. Haus. Recently, Subcommittee 7.9 of the IRE approved for the same term a definition similar to that used here. The concept underlying these definitions has been utilized previously. In the analysis of noise in conventional amplifiers, $(F-1)$ has played an important part and has been designated the excess noise figure, and $(F-1)\cdot 290$°K has been termed the excess noise (temperature). (For example, see D. T. McCoy, "Present and future capabilities of microwave crystal receivers," PROC. IRE vol. 46, pp. 61–66; January, 1958.) Also, in dealing with maser noise this concept has been used, being called "noise temperature" by others[3,11] and "effective noise temperature" by the authors.[10]

amplifying medium and a number of sources of thermal noise; the cavity walls, the input circuit, the output circuit in the two-port case, and losses in the cavity caused by the presence of the amplifying medium, *e.g.*, dielectric losses in the case of a solid sample or, as was pointed out by Muller and Helmer,[8] absorption due to background ammonia gas in the case of the ammonia beam maser. Noise due to statistical fluctuations in the number of amplifying particles is usually negligible. For example, in the ammonia beam maser, fluctuations amount to about one part in 10^5 (there are about 10^{10} molecules in the cavity at any time), and this would be expected to cause gain fluctuations less than 0.1 per cent in a maser amplifier operating at about 20-db gain. Both transmission and reflection-type operation are treated theoretically, although experimental results are given only for the reflection type. It is shown that in most cases the reflection type is better in noise figure as well as in gain-bandwidth product. Finally, the possibility of a traveling-wave maser is mentioned. It is superior to either type of cavity maser if the necessary gain can be obtained.

Consider first the general maser amplifier (Fig. 1) utilizing a resonant cavity. The cavity is coupled by two waveguides, labeled 1 and 2 for input and output respectively, and contains the "negative temperature" amplifying medium. Let there be a circulator on the cavity input so that the power returning from the cavity in waveguide 1 is separated from the input signal power. Furthermore, let there be an isolator in the output waveguide so that a constant matched load is presented to the cavity. Each of the circuit elements has some definite temperature and, if lossy, is a generator of thermal noise. Let Q_1 and Q_2 be equal to the ratio of the energy stored in the cavity to the energy per radian which emerges from the cavity into the input and output waveguides, respectively.

Consider now an equivalent circuit for the maser. At the outset no circuit losses except that of the cavity, represented by Q_c, and the backward loss of the isolator are included. The losses of the circulator and other input circuitry are taken into account later. First, replace the lossy cavity by a lossless one of the same resonant frequency to which a matched waveguide is appended through a suitable coupling (Fig. 2). The temperature of the load in this waveguide is equal to the temperature of the cavity. As for the amplifying medium, it can be shown directly from Maxwell's equations that the effect of its complex susceptibility,[13] $\chi=\chi'-i\chi''$, is to

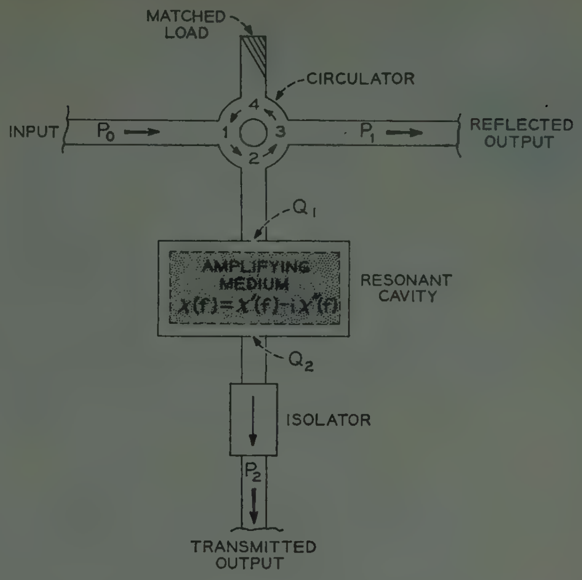

Fig. 1—Schematic diagram of a maser amplifier using a resonant cavity. Both transmitted and reflected power are indicated.

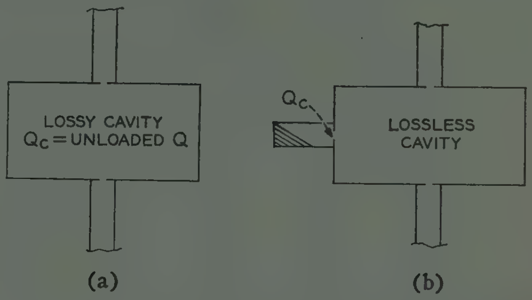

Fig. 2—(a) A lossy cavity. (b) Equivalent circuit for lossy cavity.

change the apparent Q and resonant frequency of the cavity. The impedance of the cavity plus medium measured at frequency f is equal to that of a cavity whose resonant frequency differs from that of the actual cavity by the fractional amount $\Delta f/f_c=\frac{1}{2}\eta\,\chi'(f)$, and whose losses differ by an amount $\Delta(1/Q)=\eta\,\chi''(f)$. f_c is the resonant frequency of the loaded cavity without medium; η is the filling factor[14] and is unity when the medium completely fills the cavity.

According to the results of Slater's[15] analysis, an equivalent microwave circuit may be obtained through replacement of the amplifying medium by another waveguide, whose coupling to the cavity is proportional to the sample susceptibility. This waveguide is terminated at the "plane of the detuned short" by an admittance Y whose frequency dependence is that of the sample resonance. Let χ_m be the maximum absolute value of the imaginary part of the sample susceptibility, and let $g(f)$ and $b(f)$ be line shape factors such that $\chi'=\chi_m b(f)$ and $\chi''=\chi_m g(f)$. The equivalent circuit

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[13] The electric susceptibility, $\chi(f)$, at frequency f is defined by $P(f)\cdot\exp i2\pi ft=\chi(f)\cdot\epsilon_0\cdot E(f)\cdot\exp i2\pi ft$, where $P(f)$ is the polarization produced by the electric field $E(f)$. χ' and χ'' are related to each other through the Kronig-Kramers relations. See J. H. Van Vleck, "Propagation of Short Radio Waves," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 13, D. E. Kerr, ed., p. 642; 1951.

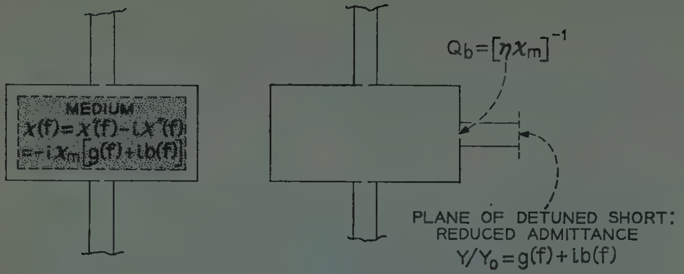
H. Fröhlich, "Theory of Dielectrics," Clarendon Press, Oxford, Eng.; ch. 1, sec. 2; 1949.

A. M. Portis, "Electronic structure of *F* centers: saturation of the spin resonance," *Phys. Rev.*, vol. 91, pp. 1071–1078; September 1, 1953.

$$=\int_{\text{sample}} E^2\,d(\text{vol})\Big/\int_{\text{cavity}} E^2 d(\text{vol})$$

for the case of an electric dipole transition. For the magnetic dipole case B replaces E.

[15] J. C. Slater, "Microwave Electronics," D. Van Nostrand Co., Inc., New York, N. Y., ch. 4; 1950.



(a) (b)

Fig. 3—(a) Resonant cavity with amplifying medium. (b) Equivalent circuit for cavity with amplifying medium.

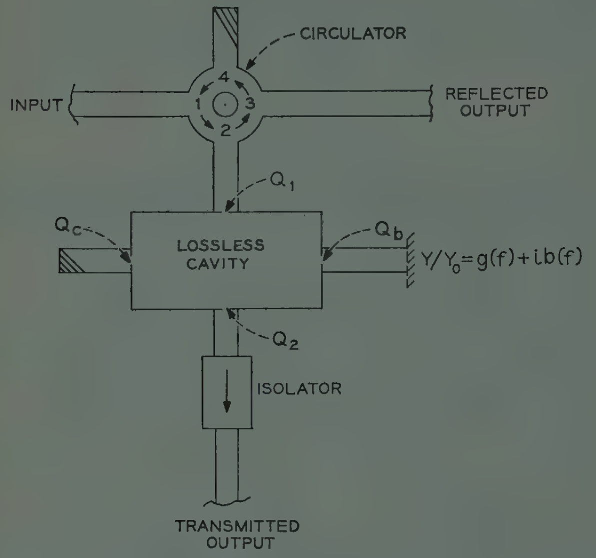


Fig. 4—Complete equivalent circuit for maser amplifier.

(Fig. 3) is then obtained by letting the coupling be $Q_b=1/\eta\chi_m$ and the reduced admittance be $y_b=g(f)+ib(f)$, where $y_b=Y/Y_0$, and Y_0 is the characteristic admittance of the guide. Positive values of g represent absorption; negative values, emission. From the definition of χ_m note that the maximum absolute value of g is always unity, and that this occurs at the center of the sample resonance. The complete equivalent circuit, then, is as given in Fig. 4.

The sources of noise in the maser amplifier now are easily discernible. Noise power traveling toward the cavity is generated by the load in each waveguide. The output isolator is considered to be an integral part of the amplifier, and therefore the noise it radiates toward the cavity is included in the analysis. This noise power is a full kT_i per unit bandwidth, corresponding to the infinite attenuation in the backward direction which the isolator is assumed to possess. T_i is the isolator's temperature. The circulator contributes noise only if it is lossy and/or if it sees a mismatch looking toward the input. Circulator loss is considered later; it is assumed mismatches can be avoided. The amplifying medium also contributes noise. It has been shown by Pound[4] that the noise generator associated with a negative resistance (in this case a negative admittance) follows the Johnson-Nyquist formulation just as for the positive resistance. Thus, for $|T_b|\gg hf/k$, noise power per unit bandwidth of amount $kT_bg(f)$[16] is incident on the cavity from this noise source, where T_b is the "temperature" (negative) of the amplifying medium,[2] defined by $T_b=-hf/k\ln(n_a/n_b)$, where n_a and n_b are the populations of the upper and lower quantum energy levels responsible for the amplification. This is the same relationship between the level populations and temperature which holds for thermodynamic equilibrium at positive temperature. Dielectric losses in the sample, if any, should be added to the cavity loss in the types of maser in which the sample is permanently affixed to the cavity and takes up the cavity temperature. In the beam-type maser there is no dielectric loss; however, background gas causes some absorption. This absorption should be added similarly to the cavity loss since the molecules responsible for it have bounced, for the most part, at least once off the walls of the cavity, and so have acquired nearly the temperature of the cavity. The relative importance of each noise source is determined by its temperature and the size of the coupling by which it is attached to the cavity.

The calculations necessary to obtain gain and noise figure are quite straightforward from this point. First, however, it is convenient to define some useful symbols:

$$Q_L\equiv\left(\frac{1}{Q_c}+\frac{1}{Q_1}+\frac{1}{Q_2}\right)^{-1},\ \text{loaded cavity } Q,$$

$\beta=Q_L/Q_b$, beam strength parameter (this factor approaches unity for high gain),

$$D(f)\equiv 4Q_L^2\left[\frac{1}{4}\left(\frac{1}{Q_L}+\frac{g(f)}{Q_b}\right)^2+\left(\frac{f-f_c}{f_c}+\frac{b(f)}{2Q_b}\right)\right],$$

resonant term

$$=(1+\beta g(f))^2+\left(\frac{f-f_c}{\Delta f_c}+\beta b(f)\right),$$

where $\Delta f_c=f_c/2Q_L$ is the half width at half maximum of the cavity resonance. The input power P_0 per unit bandwidth, causes a reflection of amount[17]

$$P_r=P_0\left[1-\frac{4Q_L^2}{DQ_1}\left(\frac{1}{Q_c}+\frac{1}{Q_2}+\frac{g}{Q_b}\right)\right]$$

and also a transmission into waveguide 2 of magnitude

$$P_t=P_04Q_L^2/Q_1Q_2D.$$

Similar equations obtain for the noise power originating from each of the noise sources. Adding up the contributions from all the different independent sources, the power P_1 per unit bandwidth which emerges from the input is

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[16] For $|T_b|\lesssim hf/k$ the exact expression, $g(f)\cdot hf/[\exp(hf/kT_b)-1]$, must be used.

[17] The explicit frequency dependence of $g(f)$, $b(f)$, and $D(f)$ is omitted from here on, and the simple forms g, b, and D used.

$$P_1 = P_0\left[1 - \frac{4Q_L^2}{DQ_1}\left(\frac{1}{Q_c} + \frac{1}{Q_2} + \frac{g}{Q_b}\right)\right] + \frac{4Q_L^2}{DQ_1}\left[\frac{kT_c}{Q_c} + \frac{kT_i}{Q_2} + \frac{kT_b g}{Q_b}\right]$$

where T_c is the temperature of the cavity. Similarly, the power P_2 per unit bandwidth emerging into waveguide 2 is

$$P_2 = P_0 4Q_L^2/Q_1Q_2D + kT_i\left[1 - \frac{4Q_L^2}{DQ_2}\left(\frac{1}{Q_c} + \frac{1}{Q_1} + \frac{g}{Q_b}\right)\right] + \frac{4Q_L^2}{DQ_2}\left[\frac{kT_c}{Q_c} + \frac{kT_b g}{Q_b}\right].$$

Now that the basic formulas have been obtained, the gain, bandwidth, noise figure, and relative merit for the transmission and reflection type masers can be evaluated. Also, these results can be compared with the experimental data.

Bandwidth of the amplifier, at high gain, is mainly determined by the resonant term D. At frequencies near the midband of the maser, g and b may be approximated by $g = -1$ and $b = (f - f_b)/\Delta f_b$, where f_b and Δf_b are, respectively, the center frequency and half width at half maximum of the amplifying resonance. For both reflected power and transmitted power, the difference B between half-power frequencies is approximately

$$B \approx 2(1 - \beta)\left[\frac{1}{\Delta f_c} + \frac{\beta}{\Delta f_b}\right]^{-1}.$$

The effective input noise temperature $T_n(f)$ is obtained by setting P_0 equal to $kT_n(f)$ and equating the part of P_1 or P_2 originating from this noise source to the combined power per unit bandwidth from the other noise sources. When dealing with the one-port maser, Q_2 is set equal to infinity to eliminate the second waveguide.

The effective input noise temperature for the one-port maser is

$$T_n(f) = \frac{\dfrac{4Q_L^2}{Q_1D}\left[\dfrac{T_c}{Q_c} + g\,\dfrac{T_b}{Q_b}\right]}{1 - \dfrac{4Q_L^2}{Q_1D}\left[\dfrac{1}{Q_c} + g\,\dfrac{1}{Q_b}\right]}. \qquad (1)$$

At resonance $(f = f_c = f_b)$ the effective input noise temperature, $T_{n,0}$, may be expressed as

$$T_{n,0} = \frac{(\sqrt{G_0} + 1)^2}{G_0}\left[T_c\,\frac{Q_1}{Q_c} + |\,T_b|\,\frac{Q_1}{Q_b}\right] \qquad (2)$$

where G_0 is the power gain at resonance, given by

$$G_0 = \frac{P_r}{P_0} = 1 + \frac{4Q_L^2}{Q_1(1 - \beta)^2}\left[\frac{1}{Q_b} - \frac{1}{Q_c}\right]. \qquad (3)$$

For the transmission-type maser at resonance

$$T_{n,0} = T_c\,\frac{Q_1}{Q_c} + |\,T_b|\,\frac{Q_1}{Q_b} + T_i\left[\left(\frac{Q_1}{Q_2}\right)^{1/2} - \frac{1}{\sqrt{G_0}}\right]$$

and

$$G_0 = \frac{4Q_L^2}{Q_1Q_2(1 - \beta)^2}.$$

One further consideration is in order, namely the effect of loss in the input circuit. This loss has two bad effects: it attenuates the signal and at the same time it introduces some noise. The effective input noise temperature T_n' of the resulting amplifier is increased over that of the maser proper, becoming

$$T_n' = [T_n + T_L(L - 1)/L]L \qquad (4)$$

where L is the loss (reciprocal of the gain) and T_L is the temperature of the element which introduces the loss. The effect of input loss may be important in maser amplifiers, especially the reflection type where the required circulator may introduce as much as a few tenths of a db of loss.

Contemplation of the above results reveals the following facts, assuming the same sample in both reflection and transmission-type operation.

1) For the same value of the loaded cavity Q, and thus the same bandwidth, the gain of the reflection type is 6 db greater than the maximum gain of the transmission type, which is obtained by setting $Q_1 = Q_2$. Also, contributions to the effective input noise temperature from the amplifying material and the cavity walls are higher for the transmission-type maser; they are about twice as large in the case $Q_1 = Q_2$.
2) For reasonably low noise operation and at the same time high gain, it is essential to cool the isolator of the transmission-type amplifier to a low temperature, whereas the circulator of the reflection type need not be cooled if its loss is kept small.
3) For minimum noise operation, it is necessary to cool the input circuit and the resonant cavity for either type of maser.

A word about the possible operation of a traveling-wave maser amplifier is appropriate at this point. The instability and loss in bandwidth, which are common to all types of regenerative amplifiers at high gain, are largely overcome by this method, and its noise properties are similar to those of the cavity maser. However, for some types of amplifying media, *e.g.*, gases, it is very difficult to produce the high concentration of field which is necessary in such a device to obtain useful gain in a reasonable volume.

EXPERIMENTAL PROCEDURE

The aim of the experiment was to measure the effective input noise temperature of an ammonia maser and to compare this experimental value with theory.

A block diagram of the apparatus used in making the noise measurements is shown in Fig. 5. With the exception of the liquid nitrogen cooled load, all of the microwave plumbing, including the masers' cavities, was at room temperature. Each maser was similar to that described by Gordon, Zeiger, and Townes[1] and was of the reflection type. The cavities were operated in the TM_{010} mode. A circulator separated each maser's output from its input. The effective input noise temperature to be measured was that of the first maser. The coupling of its cavity was increased until sufficient gain was achieved with the strongest available beam. A considerable overcoupling, $(Q_1/Q_c<1)$, resulted, giving an expected effective input noise temperature much less than the cavity temperature [see (2)]. The amplification of the first maser was modulated[18] on and off at 35 cps by a square-wave transverse electric field within the cavity. To obtain this field the cavity was split longitudinally and a voltage was applied between the two halves. The resulting inhomogeneous field turned the maser OFF by broadening the ammonia resonance and shifting its peak to the extent that the effects of the beam became negligible. The second maser functioned as a CW low noise RF amplifier. The local oscillator klystron was stabilized with a dc Pound stabilizer circuit.[19] The IF amplifier operated at 70 mc and had a bandwidth of 2.5 mc. The time constant of the dc filter following the lock-in amplifier was about one second.

Measurements were made of the change in RF attenuation A that followed the second maser required to keep the recorder deflection constant as the temperature of the nonreflecting input termination was changed from one known temperature T'' to another, T'. This change in termination temperature was accomplished by inserting 20 db of room temperature attenuation between the cold load and the circulator. From these measurements alone an approximate value (within a few per cent) for the effective input noise temperature of the maser plus its input circuitry may be calculated. Measurements also were made of the loss L and the temperature T_L of the loss between the input termination and the maser cavity. From the combined measurements, an approximate value T_n^* may be obtained for the effective input noise temperature of the maser itself. A more exact determination of the effective input noise temperature T_n requires a knowledge of the relative amount of power leaving the maser when off.

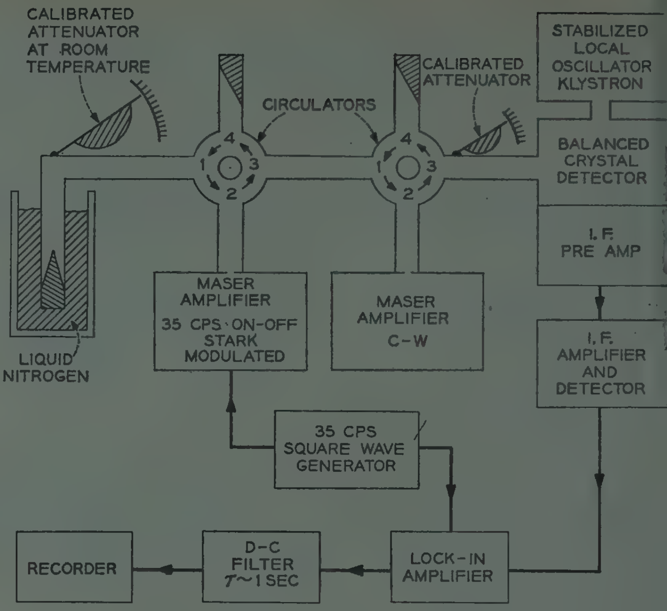
CALIBRATED ATTENUATOR AT ROOM TEMPERATURE
CIRCULATORS
CALIBRATED ATTENUATOR
STABILIZED LOCAL OSCILLATOR KLYSTRON
BALANCED CRYSTAL DETECTOR
I. F. PRE AMP
I. F. AMPLIFIER AND DETECTOR
4
1
3
2
4
1
3
2
LIQUID NITROGEN
MASER AMPLIFIER 35 CPS ON-OFF STARK MODULATED
MASER AMPLIFIER C-W
35 CPS SQUARE WAVE GENERATOR
RECORDER
D-C FILTER $\tau \sim 1$ SEC
LOCK-IN AMPLIFIER

Fig. 5—Block diagram of apparatus.

The difference between T_n and T_n^* is of the order o T_n/G_0, and was obtained from measurements of the maser gain[20] when on G_0, the maser gain when off $G°$, and the temperature of the cavity T_c.

Interpretation of Data

Before considering the actual case, consider an idea case which yields a simpler relationship between the effective input noise temperature and the measured quantities. Assume that there was zero noise power leaving the maser when it was off, that the second maser's gain was high, and that the bandwidth of the second maser was much narrower than that of the first. In this case, the change A in RF attenuation following the second maser required to keep the recorder deflection constant as the temperature of the first maser's input termination was changed from T'' to T' is related to the effective input noise temperature $T_n'(f_2)$ of the combination of the maser and its input circuitry by

$$\frac{T_n'(f_2)+T''}{T_n'(f_2)+T'}=A, \qquad (5)$$

where f_2 is the center frequency of the second maser. The effective input noise temperature $T_n(f_2)$ of the maser itself would be related to the above quantities and to the loss L and temperature T_L of the circuitry between the input termination and the maser by (4), or by

$$\frac{T_n(f_2)+T''/L+T_L(L-1)/L}{T_n(f_2)+T'/L+T_L(L-1)/L}=A. \qquad (6)$$

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[18] R. H. Dicke, "The measurement of thermal radiation at microwave frequencies," *Rev. Sci. Instr.*, vol. 17, pp. 268–275; July, 1946. This method of modulating the desired signal has a theoretical sensitivity for given IF bandwidth and dc filter time constant comparable to that obtained by making CW measurements. However, in practice, better sensitivity usually is obtained with the modulation technique because it is less sensitive to slow gain fluctuations in the superheterodyne receiver.

[19] R. V. Pound, "Frequency stabilization of microwave oscillators," Proc. IRE, vol. 35, pp. 1405–1415; December, 1947.

[20] The signal used for the gain measurement was derived from tha of the local oscillator by a 70 mc modulator and a sideband filter.

Though not stated explicitly, (5) and (6) also assume hat both masers were acting as linear amplifiers, which assumption should be valid at the power levels of operaion.

The assumptions that the noise leaving the maser when off was zero, and that the second maser's bandwidth was much narrower than that of the first, were only approximately correct. As a result, (5) and (6) are no longer exact. However, for purposes of comparing experiment and theory it is convenient to use a quantity T_n^* defined by a relation similar to (6):

$$\frac{T_n^* + T''/L + T_L(L-1)/L}{T_n^* + T'/L + T_L(L-1)/L} = A. \tag{7}$$

Thus, T_n^* is a number which may be experimentally determined with no knowledge of the maser's characteristics.

A theoretical value for T_n^* may be obtained from measurements of the maser's characteristics and the frequency dependence of the amplification between the (first) maser and the IF detector. The recorder deflection was a function of the difference between the power arriving at the detector when the maser was on, P, and that arriving at the detector when the maser was off, P°. This difference is

$$P - P^\circ = k\int_0^\infty ([T_n + T/L + T_L(L-1)/L]G - [T_n^\circ + T/L + T_L(L-1)/L]G^\circ)G_2'df.$$

T is the temperature of the input termination, T_n° and G°, respectively, are the effective input noise temperature and gain of the maser when it is off, and G_2' is the power gain between the output of the first maser and the IF detector. Equating this power difference for the case of the input termination at the temperature T'' with that for the input termination at T' and the RF attenuation changed by A, and arranging the terms into the form of (7), yields for the theoretical value of T_n^*

$$T_n^* = \frac{\int_0^\infty [T_nG - T_e(1-G^\circ)]G_2df}{\int_0^\infty (G-G^\circ)G_2df}, \tag{8}$$

where G_2 has the frequency dependence of the amplification between the first maser and the IF detector. A is assumed constant over the frequency range of interest. In (8), $T_e(1-G^\circ)$ has been substituted for $T_n^\circ G^\circ$. This is a valid substitution because the effects of the beam were negligible when the maser was off and thus G° is the reflection coefficient of the cavity. In our case, a sufficiently accurate evaluation of (8) is possible, even though the exact frequency dependence of G and G_2 is unknown. In the frequency region where the gain of the first maser is a few db or more, the ratio of $T_nG-T_e(1-G^\circ)$ to $G-G^\circ$ is very nearly independent of frequency. Furthermore, the contribution to (8) from outside this region is negligible (see Appendix I). Thus, (8) reduces to

$$T_n^* = \frac{T_nG - T_e(1-G^\circ)}{G-G^\circ} = \frac{T_{n,0}G_0 - T_e(1-G^\circ)}{G_0 - G^\circ} \tag{9}$$

with an estimated uncertainty in T_n^* of about 1 per cent, arising from lack of exact knowledge of the shape of the ammonia resonance. For these equations to hold, it is required that the resonant frequency of the maser cavity, the resonant frequency of the ammonia beam, and the center frequency of the second maser be identical; it is sufficient if these frequencies are close enough to each other for good operation.

Eq. (9) combined with (2) yields a theoretical value of T_n^* depending only upon the maser's characteristics. This theoretical value may be compared with the experimental value given by (7). However, since the effective input noise temperature is of more interest than T_n^*, (7) and (9) were combined to give the following expression for the experimental value of $T_{n,0}$:

$$T_{n,0} = \left[\frac{AT' - T''}{1-A}\frac{1}{L} - T_L\frac{L-1}{L}\right]\left(1 - \frac{G^\circ}{G_0}\right) + T_e\frac{1-G^\circ}{G_0}; \tag{10}$$

and this experimental value was compared with the theoretical value of $T_{n,0}$ as given by (2).

Results

Three separate sets of measurements were made. The results are summarized in Table I as follows.

TABLE I
Results

Date	T_{room} °K	A	L	G°	G_0	T_n Experimental	T_n Theoretical
June 10, 1957	300	2.00 ±0.05	1.172 ±0.027	0.473 ±0.011	50 ±5	81 ±18	77 ±3
June 25, 1957	307	2.04 ±0.14	1.177 ±0.014	0.505 ±0.030	45 ±7	78 ±30	75 ±7
July 18, 1957	304	1.95 ±0.05	1.232 ±0.020	0.513 ±0.013	71 ±7	74 ±16	68 ±3

$T'' = (T_{\text{room}} - 2)$ °K
$T' = 77$°K
$T_L = T_e = T_{\text{room}}$

The results of June 10, 1957, and July 18, 1957 have been reported previously.[10] In that report, the experimental and theoretical values of the effective input noise temperature were only approximate; the experimental numbers were the T_n^* of the present paper, and the theoretical numbers did not include the contribution of the background ammonia.

The experimental values given in Table I for the effective input noise temperature T_n of the maser, *i.e.*, cavity plus medium, were obtained from (10).

The theoretical values of the effective input noise temperature were calculated from (2) with $1/Q_c$ representing the losses both in the cavity walls and in the background ammonia. The "temperature" of the beam was negative and probably much smaller in absolute magnitude than hf/k. As a result, in (2) $|T_b|$ should be replaced by $hf/k = 1.1$°K. The contribution to the effective input noise temperature by the background ammonia was estimated to be 3.4°K (see Appendix II). The calculation of the theoretical value was based on measurements of the cavity temperature, the reflection coefficient of the cavity with no beam, the midband maser gain, and the pressure of the background ammonia.

The experimental and theoretical values for the effective input noise temperature of the maser agree well within the experimental error. The contribution of the beam to the maser noise was too small to be measured. However, an upper limit of approximately 20°K can be placed on the absolute value of the beam temperature.

APPENDIX I

The difference in power per unit bandwidth between maser on and maser off is much larger in the frequency region of high gain than in the "tail" of the ammonia resonance. However, the effect of the tail on T_n^* may be significant, depending upon the frequency dependence of the gain G_2 following the maser. For example, if G_2 is constant over a frequency region which is large compared to the width of the cavity resonance, evaluation of (8) yields

$$T_n^* = T_{n,0}\,\beta\,\frac{(Q_c/Q_b) - 1}{(Q_c/Q_b) - \beta}$$

where it is assumed that the ammonia resonance has a Lorentz shape, *i.e.*, $g = -1/[1 + ((f - f_b)/\Delta f_b)^2]$. Using values of $\beta(\sim 0.8)$ and $Q_c/Q_b(\sim 5)$ appropriate to the maser as operated gives $T_n^* \sim (3/4)T_{n,0}$. The frequency region responsible for most of this difference between T_n^* and $T_{n,0}$ is the tail of the ammonia resonance. The exact line shape of the actual resonance is not known. However, enough is known to be able to state that the relative contribution to T_n^* from the tail of the resonance is the same order of magnitude as the contribution from the tail of a Lorentz-shaped line. In the actual experiment G_2, determined by the product of the second maser and the IF amplifier gains, was strongly peaked. In the vicinity of the ammonia resonance G_2 was more than 30 db larger than in the tail. Thus the contribution to T_n^* from the tail was negligible.

APPENDIX II

Eq. (2) can be extended to include the contribution, $\Delta T_{n,0}$, to the effective input noise temperature from the background ammonia gas. The loss, $1/Q_{\text{gas}}$, due to these stray ammonia molecules is simply added to the cavity loss, giving $\Delta T_{n,0} = [(\sqrt{G_0} + 1)^2/G_0]T_cQ_1/Q_{\text{gas}}$. An estimate of $1/Q_{\text{gas}}$ may be made from the known absorption coefficient of the ammonia 3-3 line, $\alpha = 7.9 \times 10^{-4}$ cm^{-1}; the background pressure p of ammonia in the cavity chamber; the gas pressure p_0 at which molecule-molecule collisions and molecule-wall collisions make equal contributions to the line width, and the free space wavelength λ_0. The appropriate relationship for the case $p \ll p_0$ is

$$\frac{1}{Q_{\text{gas}}} \cong \frac{\alpha\lambda_0 p}{2\pi p_0}.$$

Taking values approximating the experimental conditions,

$$p_0 = 1 \times 10^{-3} \text{ mm Hg}$$
$$p = 3 \times 10^{-5} \text{ mm Hg}$$
$$\lambda_0 = 1.25 \text{ cm},$$

yields $1/Q_{\text{gas}} \cong 1.8 \times 10^{-6}$. The resulting contribution to the effective noise temperature is $\Delta T_{n,0} \cong 3.4$°K, where the values $Q_1 = 1800$, $G_0 = 50$, and $T_c = 300$°K have been assumed.

ACKNOWLEDGMENT

The authors gratefully acknowledge many helpful discussions with Prof. C. H. Townes, Dr. R. Kompfner and Dr. C. F. Quate; circulator components and advice on circulator construction from Dr. E. H. Turner and Dr. E. A. Ohm; considerable experimental assistance from J. M. Dziedzic and J. J. Wiegand; and some valuable comments from the unknown reviewers.

The Spherical Coil as an Inductor, Shield, or Antenna*

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Summary—**The spherical coil is an idealized form of inductor aving, on a spherical surface, a single-layer winding of constant xial pitch. Its magnetic field inside is uniform and outside is that of . small coil or magnetic dipole. Its properties exemplify exactly some f the rules that are approximately applicable to practical inductors. imple formulas are given for self-inductance, mutual inductance, oupling coefficient, effect of iron core, and radiation power factor in ree space or sea water. This coil is the basis for evaluating the hielding effect of a closed conductive (nonmagnetic) metal shell. A pecial winding is described which enables simple and exact computation of self-resonance (the length of wire being just ½ wavelength n some cases).**

I. INTRODUCTION

A SPHERICAL coil is an inductor similar to the solenoid but spherical rather than cylindrical in shape. Its internal magnetic field is constant and its external field is that of a small magnetic dipole.

The spherical coil was described by Maxwell in his monumental treatise [1] but it has been ignored by subsequent workers. It has little practical value in its iteral form but its study leads to relationships that have qualitative significance in many practical situations. The present purpose is to present some of these relationships in a form that will suggest their practical mplications.

This is an example of one philosophy of approximation, the one that seeks for idealized forms that are susceptible of simple and exact formulation. These orms are then perceived as approximations of practical orms. Being exactly formulated, any relationships are ikely to indicate real trends.

The writer first developed some concepts of the pherical coil in 1941 while studying the problems of an lectromagnetic detector for buried metal objects [3]. A spherical coil on short-circuit was used to simulate he reaction from an object made of a conducting shell. The outcome of this work was the SCR-625 mine detector which was the one used by our armed forces in World War II.)

More recently, the writer formulated the ideal properties of a spherical radiator that can be approximated in a loop antenna on a spherical iron core. Also, there will be presented here a set of idealized conditions in which a coil of wire is self-resonant at a frequency such that the length of wire is just ½ wavelength.

After a preliminary description of spherical coils, there will be formulated their various properties of self and mutual inductance, shielding, radiation and self-resonance. Attention will be paid to the core space, including a magnetic or antimagnetic sphere partially filling the coil.

II. SYMBOLS

MKS Rationalized Units

L = inductance (henries).
C = capacitance (farads).
R = resistance (ohms).
$\mu_0 = 1.257\times10^{-6}$ = magnetivity (permeability) of free space (henries/meter).
$\epsilon_0 = 8.85\times10^{-12}$ = electrivity (permittivity) of free space (farads/meter).
$R_c = 377$ = wave resistance of free space (ohms).
ω = radian frequency (radians/second).
λ = wavelength (meters).
$\lambda/2\pi$ = radianlength (meters).
σ = conductivity (mhos/meter).
δ = skin depth (meters).
a = radius (meters).
c = pitch of winding (meters).
d = thickness of conductor winding or shell (meters).
l = length of wire on coil (meters).
r = distance between centers (meters).
A = total area of turns (meters²).
V = volume of spherical coil (meters³).
V_r = volume of radiansphere (meters³).
n = number of turns.
k, k', k_1, k_m = magnetic ratio (relative permeability).
k_e = electric ratio (dielectric constant).
k_{12} = coefficient of coupling.
$p = R/L\omega$ = power factor (much less than unity).
p_2 = leakage fraction of spherical shell (free of skin effect).
p_s = leakage fraction of spherical shell (subject to skin effect).
E = voltage between ends of coil (volts RMS).
I = current at middle of coil (amperes RMS).

III. THE SPHERICAL COIL

Fig. 1 shows some of the properties of the spherical coil. It is to be wound in such a way that the internal magnetic field is uniform, as indicated in Fig. 1(a). This requires a current sheet with the turns pitched uniformly along the axis, as shown in Fig. 1(b). The variation of the length of wire per turn is such that its average is $\pi/4$ of the middle turn at the equator. The varying area of the turns is graphed in Fig. 1(c). The parabola

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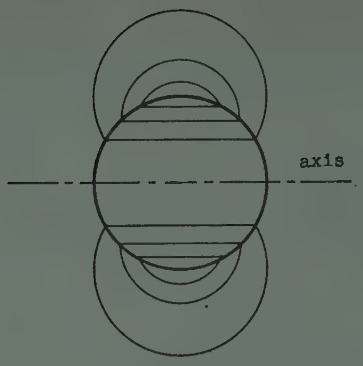
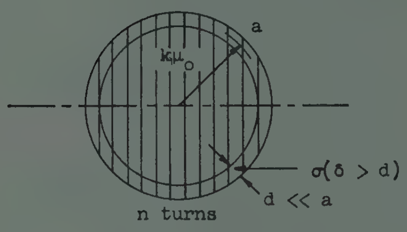
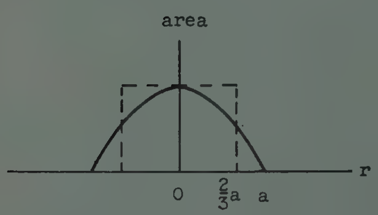


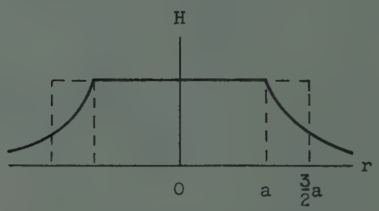
(a) Magnetic field.



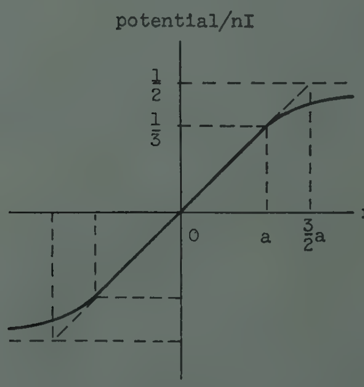
(b) Spherical coil.



(c) Relative area per turn.



(d) Relative field intensity.



(e) Relative magnetic potential.

Fig. 1—The spherical coil and its properties.

shows the variation of the area per turn, such that its average is $\frac{2}{3}$ of the area at the equator. The other curves (d) and (e) will be discussed later.

The concept of the current sheet is familiar in the study of inductance. Ideally it requires many turns of small wire, rather closely spaced but in accordance with the prescribed variation of pitch. As a result, the inductance is mainly obtained by interaction of the turns and is nearly independent of the fine structure of the turns.

Among all forms of inductors, the spherical coil yields the simplest formulation of its properties. The basic reason for this is that its field pattern involves spherical harmonics of orders zero and one, which correspond to a uniform field and to that of a small dipole. Unlike the closed-core or toroidal inductors, the spherical coil has the external field required for radiation or other exterior coupling.

IV. SELF-INDUCTANCE

The inductance formula will be derived in a succession of easy steps relying only on simple rules, referring to Fig. 1.

The starting point is a cylindrical coil of radius a, length $2a$, and n turns. The cylindrical volume has an air core and is surrounded by a perfect magnetic medium; the respective magnetic ratios are $k=1$ and $k'=\infty$. The interior field is uniform. The inductance is

$$\text{cyl } L(1,\ \infty) = \mu_0 \frac{\pi a^2 n^2}{2a} = \frac{\pi}{2} \mu_0 a n^2. \tag{1}$$

Taking next the spherical coil with corresponding air core and magnetic surrounding, the volume is $\frac{2}{3}$ as great so the magnetic energy and the inductance are multiplied by this factor. The inductance of the sphere, with $k=1$ and $k'=\infty$, is

$$L(1,\ \infty) = \frac{\pi}{3} \mu_0 a n^2. \tag{2}$$

This inductance is limited by the internal reluctance, with no external reluctance.

In order to learn the relative reluctance of internal and external paths for magnetic flux, some computations are made with the spherical coil in air. By integration over the turns of the coil, the magnetic field along the axis is found to follow two laws, graphed in Fig. 1(d). Inside the coil, the magnetic field is uniform. Outside the coil, the field varies inversely with the cube of the distance from the center (as in the case of a small coil or magnetic dipole). Integrating this field along the axis, we obtain the magnetic potential, graphed in Fig. 1(e). The total potential difference along the axis is nI for n turns carrying current I. It is found that $\frac{2}{3}$ of the potential is inside the coil and $\frac{1}{3}$ is outside. Therefore the path reluctance outside is $\frac{1}{2}$ as great as that inside. The inuctance of the spherical coil in air is $\frac{2}{3}$ as great as (2) bove:

$$L = \frac{2\pi}{9}\mu_0 a n^2. \tag{3}$$

'he general formula, for any magnetic ratios inside and utside, is

$$L(k, k') = \frac{2\pi}{9}\mu_0 a n^2 \frac{1}{2/3k + 1/3k'} = \frac{2\pi}{9}\mu_0 a n^2 \frac{3}{2/k + 1/k'}. \tag{4}$$

The resistance of the spherical coil is of interest in ome applications. In Fig. 1(b), the conducting shell is ndicated as having a thickness d much less than the adius a. The conducting cross section of this shell is ssumed to determine that of the wires in the current heet. It is also assumed that this thickness is much ess than the "skin depth" in the conducting material t the operating frequency. The resistance per turn is ess toward the poles because the turns are shorter and vider; the variation follows the parabola in Fig. 1(c) so he average per turn is $\frac{2}{3}$ of the resistance of the longest urn at the equator. On this basis, the resistance of the oil is

$$R = \frac{2\pi n^2}{3d\sigma}. \tag{5}$$

The power factor of this inductor (in air) is:

$$p = R/L\omega = \frac{3}{\omega\mu_0\sigma a d} = \frac{3\delta^2}{2ad}. \tag{6}$$

'he condition that $d < \delta$ is still in effect, so this formula limited to $p > 3d/2a$. The last form is simplified to a atio of length dimensions by introducing the skin epth (though this case is not subject to the skin effect).

If the winding on the spherical coil is subject to the kin effect, no simple evaluation is apparent because ne magnetic flux links the winding.

Fig. 2 shows a simple solenoid that has certain proper- es of the spherical coil exactly, and some other proper- es approximately. The following properties are the ame:

Radius (at equator)
Axial pitch of turns
Total area of turns (and resulting far field)
Total resistance of turns.

he following properties are different:

Greater maximum dimension (radius of circumscribed sphere is greater in ratio $\sqrt{13/9} = 1.20$)
Lesser axial length (2/3)
Lesser number of turns (2/3)
Lesser field intensity on axis
Lesser inductance (approximately 0.917 or 11/12).

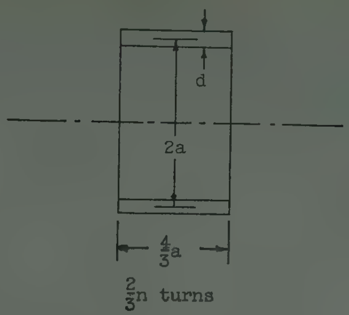
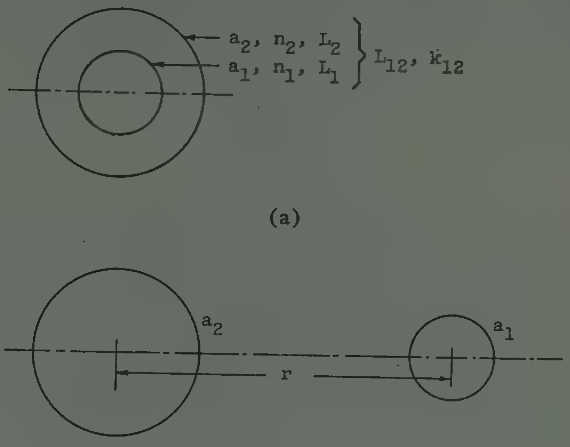


Fig. 2—Solenoidal coil for comparison.



(a)

(b)

Fig. 3—Two coaxial spherical coils.

The inductance of this solenoid is given by

$$\text{sol } L = \mu_0 \frac{\pi a^2(\frac{2}{3}n)^2\, 0.595}{\frac{2}{3}(2a)} = \frac{2\pi}{9}\mu_0 a n^2\left(\frac{3}{2}0.595\right) = \frac{2\pi}{9}\mu_0 a n^2(0.893). \tag{7}$$

The last form shows the ratio by which this inductance is less than that of the spherical coil.

V. Mutual Inductance

Fig. 3 shows the two cases of mutual inductance between two spherical coils, the smaller coil being inside or outside of the larger coil.

In Fig. 3(a), the smaller of two coils is inside the larger, with parallel axes. They need not be concentric or even coaxial. The mutual inductance is computed easily because of the uniform field inside the larger coil.

$$L_{12} = L_2 \frac{n_1 a_1^2}{n_2 a_2^2} = \frac{2\pi}{9}\frac{\mu_0 a_1^2 n_1 n_2}{a_2}. \tag{8}$$

Their coefficient of coupling is

$$k_{12} = L_{12}/\sqrt{L_1 L_2} = (a_1/a_2)^{3/2} \tag{9}$$

$$k_{12}^2 = (a_1/a_2)^3 = V_1/V_2 \tag{10}$$

in which V_1 and V_2 are the volumes of the spheres.

A practical application of a spherical coil (somewhat different from the ideal) is found in the so-called "variometer." This device is an inductor made of two concentric spherical coils of nearly the same size, the inner one rotating about a transverse axis. The two coils are connected in series (or parallel) to form an inductor that has a wide ratio of variation obtained by changing the mutual inductance from "opposing" to "aiding."

In Fig. 3(b) the two coils are mutually external and coaxial. Since the external field of each coil follows exactly the pattern of a small coil or magnetic dipole, the mutual inductance is expressed by a simple formula (derived from principles given by Harnwell [9]).

$$L_{12} = \frac{2\pi}{9} \frac{\mu_0 a_1^2 a_2^2 n_1 n_2}{r^3} \tag{11}$$

$$k_{12} = (a_1 a_2 / r^2)^{3/2}. \tag{12}$$

The ultimate simplicity of this formula is attributable to the simple properties of the spherical coil.

If instead, the equators of the two coils are coplanar, the values of L_{12} and k_{12} are $\frac{1}{2}$ as great.

The greatest coefficient of coupling between two coils mutually external is obtained with two coaxial coils of the same size in contact:

$$r = 2a_1 = 2a_2 : k_{12} = 1/8. \tag{13}$$

If each of two coaxial coils is filled with a magnetic core (k_1 or k_2), their mutual inductance is increased more than their self-inductance, so their coefficient of coupling is increased approximately as follows:

$$k_{12} = \left(\frac{a_1 a_2}{r^2}\right)^{3/2} \left(\frac{3k_1}{2 + k_1} \quad \frac{3k_2}{2 + k_2}\right)^{1/2} \tag{14}$$

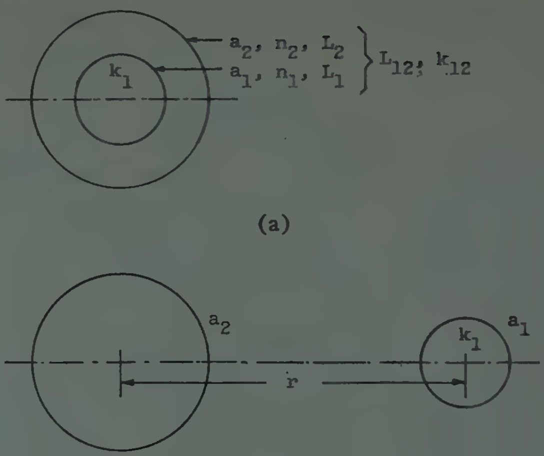
This formula is based on the assumption of a separation far from contact. Perfect magnetic cores increase the coupling by a factor of 3.

Comparing two coaxial coils of the solenoid form (Fig. 2) located far apart, we find that their mutual inductance is the same and their coefficient of coupling is greater approximately in the ratio 1/0.893 = 1.120. This increase is attributed to the larger maximum dimension of each coil.

VI. Spherical Core

There has been some mention of a magnetic core completely filling a spherical coil. Fig. 4(a) shows the more general case of a concentric spherical core partially filling the coil. It is regarded as a coaxial smaller coil filled with a core of magnetic ratio k_1.

Several simple rules enable the computation of the effect of the inside core and coil. First, L_1 and therefore L_{12} are multiplied by $3k_1/(2+k_1)$. Second, the "leakage inductance" $L_2(1-k_{12}^2)$ is unaffected by the core; it is the inductance of the outer coil with the inner coil on short-circuit. With the core, the properties involving th outer coil are changed to the following:



(a)

(b)

Fig. 4—Spherical core or external object.

$$k_{12}^2 = \frac{3k_1(a_1/a_2)^3}{2 + k_1 + 2(k_1 - 1)(a_1/a_2)^3} \qquad (1$$

$$L_2 = \frac{2\pi}{9} \mu_0 a_2 n_2^2 \left[1 + 2\frac{k_1 - 1}{k_1 + 2}(a_1/a_2)^3\right]. \qquad (1$$

The last factor (in brackets) is the ratio in which th inductance of the outer coil is increased by a magneti core inside, or decreased by an antimagnetic core. Th latter might be realized by a conducting core that ex cludes magnetic flux by virtue of the skin effect, i which case $k_1 = 0$:

$$L_2 = \frac{2\pi}{9} \mu_0 a_2 n_2^2 [1 - (a_1/a_2)^3]. \qquad (1$$

This value is reduced in the ratio of the volume outsid the antimagnetic core.

As an example, take an iron-dust core of $k_1 = 4$, fillin $\frac{1}{2}$ the volume of a spherical coil. The inductance is in creased in the ratio 3/2. A solid copper core of the sam volume, shielded by the skin effect, would reduce th inductance to $\frac{1}{2}$.

Referring again to the solenoid of Fig. 2, and insertin a cylindrical core of the same shape as the solenoid, th change of its inductance would be somewhat less tha that computed for the spherical coil.

VII. External Object

Fig. 4(b) shows a spherical object (of magnetic rati k_1) external to a spherical coil. The reaction of this ob ject on the inductance of the coil forms one basis for th detection of metal bodies, exemplified by the mine de tector.

The formulas for this effect are the same as for th internal core, except for the different coefficient c coupling. In (15)–(17) above, we can change:

from $(a_1/a_2)^3$ to $(a_1 a_2/r^2)^3$.

The inductance of the coil becomes

$$L_2 = \frac{2\pi}{9}\mu_0 a_2 n_2^2\left[1 + 2\frac{k_1 - 1}{k_1 + 2}(a_1 a_2/r^2)^3\right]. \qquad (18)$$

The last factor shows the change of inductance caused by the external object; the change is inversely proportional to the sixth power of the distance.

As an example, take the external object to be an antimagnetic (conducting) sphere, and take the dimensions $a_1 = a_2 = r/10$. The change of inductance is 1 part in a million.

VIII. SPHERICAL SHIELD

Fig. 5(a) shows a spherical coil (a_1) enclosed by an external spherical shield (a_2) that is both coaxial and concentric. The shield is essentially a spherical coil on short-circuit. Its purpose is to confine the magnetic field of the coil inside, that is, to act as a magnetic shield between the inside space and the outside space. The magnetic field that penetrates the shield and reaches the outside space is sampled by the coaxial outside coil (a_3).

If the shield has a conductor thickness less than the skin depth ($d_2 < \delta_2$), the shielding action can be represented by the equivalent network shown in Fig. 5(b). (See [2].) In this network, the coupling among three nductors is uniquely reduced to a single transformer with unity coupling, supplemented by a "leakage inductance" in each circuit. The leakage inductance of L_2 becomes zero if $k_{12}k_{23} = k_{13}$. This is found to be true for the three spherical coils in Fig. 5(a). Therefore the leakage inductance of L_2 is zero, leaving its resistance R_2 as a direct shunt on the coil L_2 of the coupling transformer. If this resistance were zero, there would be zero coupling between L_1 and L_3, and hence zero magnetic field outside the spherical shield L_2.

There is a small amount of leakage through the shield f $R_2 \ll \omega L_2$, or $p_2 \ll 1$. Assuming that L_1 and L_3 are not oo close to the shield L_2, the short-circuit on L_2 reduces he coupling therebetween by the factor p_2. Therefore his factor may be denoted the "leakage fraction," and ts value is given by (6) applied to L_2.

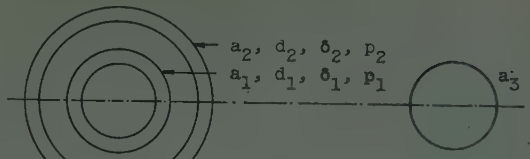
By ordinary circuit theory, it is easy to compute the properties of the inside coil L_1 as modified by the presnce of the shield effectively decreasing the inductance nd increasing the resistance. The modified properties re:

$$L_1' = L_1(1 - k_{12}^2) \qquad (19)$$

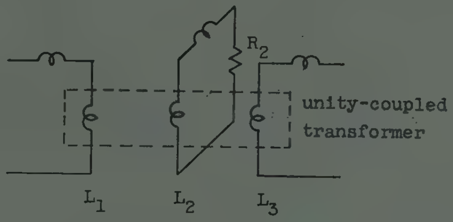
$$R_1' = R_1\left(1 + k_{12}^2\frac{R_2 L_1}{R_1 L_2}\right) = R_1(1 + k_{12}^2 p_2/p_1) \qquad (20)$$

$$p_1' = p_1\frac{1 + k_{12}^2 p_2/p_1}{1 - k_{12}^2} \qquad (21)$$

$$k_{12}^2 = V_1/V_2; \qquad k_{12}^2 p_2/p_1 = \frac{a_1^4 d_1 \delta_2^2}{a_2^4 d_2 \delta_1^2}. \qquad (22)$$



(a) Geometry.



(b) Equivalent network.

Fig. 5—Spherical shield.

The last expression shows how much the power factor of the shield is coupled into the coil inside.

A spherical shell of conducting material behaves like a spherical coil on short-circuit, so the formulas are valid for this kind of a shield.

If the thickness of the shield is greater than the skin depth ($d_2 > \delta_2$), the leakage is reduced by the skin effect. The modified leakage fraction becomes

$$p_s = p_2(2\sqrt{2})\frac{d_2}{\delta_2}\exp -\frac{d_2}{\delta_2} = \sqrt{2}\frac{3\delta_2}{a_2}\exp -\frac{d_2}{\delta_2}. \qquad (23)$$

It is noted that the formulas give nearly equal values of p_2 and p_s, as they should, if $d = \delta$.

If completely subject to the skin effect, the shield appears to have a higher power factor as follows, substituting δ for d in (6):

$$p_2 = \frac{3\delta_2}{2a_2}. \qquad (24)$$

Substituting this for p_2 in (21) and (22), but leaving p_1 the same (no skin effect in L_1):

$$k_{12}^2 p_2/p_1 = \frac{a_1^4 d_1 \delta_2}{a_2^4 \delta_1^2}. \qquad (25)$$

As an example, take a spherical shell of copper, operating at 15 kc.

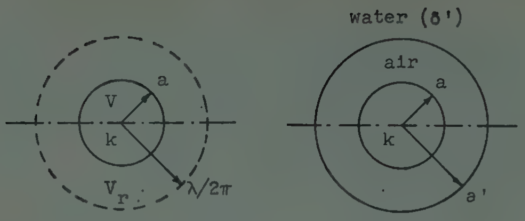
$$a_2 = 25 \text{ mm}; \qquad d_2 = \delta_2 = 0.5 \text{ mm}.$$

This is a case of marginal skin effect. The leakage fraction is:

$$p_2 = 0.03 \text{ [see (6)]}$$

$$p_s = 0.03(1.04) = 0.0312 \text{ [see (23)]}.$$

The shielding by a closed metal shell is noncritical to the shape, whereas the shielding by a coil on short-circuit is critical to both shape and orientation.



(a) In free space. (b) In sea water.

Fig. 6—Spherical coil as small antenna.

IX. Spherical Antenna

A spherical coil that is much smaller than the radiansphere in space has radiation properties that are easily computed. Fig. 6(a) shows such a coil in relation to the radiansphere. (See [14].)

The reactance may be expressed in terms of the wavelength:

$$\omega L = \frac{4\pi^2}{9} R_c \frac{an^2}{\lambda} \frac{3}{1 + 2/k} \cdot \tag{26}$$

The radiation resistance is computed from the basic formula for a small coil:

$$R = \frac{2}{3} \frac{R_c}{4\pi} \left(\frac{2\pi\sqrt{A}}{\lambda} \right)^4 = 20 \left(\frac{2\pi\sqrt{A}}{\lambda} \right)^4 . \tag{27}$$

This is in terms of the total effective area of turns, which is, in the spherical coil,

$$A = \frac{2}{3} \pi a^2 n \frac{3}{1 + 2/k} \cdot \tag{28}$$

One property of a small antenna is the radiation power factor, which depends primarily on the size and is independent of the number of turns [6]. For the spherical coil, the radiation power factor is:

$$p = \frac{R}{\omega L} = \left(\frac{2\pi a}{\lambda} \right)^3 \frac{3}{1 + 2/k} = \frac{V}{V_r} \frac{1}{1 + 2/k} \cdot \tag{29}$$

The greatest value would be obtained with a perfect magnetic core ($k = \infty$), in which case the radiation power factor would equal the volume ratio of the two spheres. This is an upper limit that may be used as a standard of comparison for practical antennas. The formula for this ideal is the ultimate in simplicity, and this power factor can nearly be realized in practice.

Fig. 6(b) shows another case, in which a spherical coil is used as a small antenna submerged in sea water. The water surrounds a spherical radome (of radius a') enclosing the coil. The radome is assumed to be much smaller than the radianlength or skin depth (δ') in the water. Then the nearby conduction in the water is limited by its conductivity rather than the skin effect [18].

The currents induced in the water are computed for a continuous series of spherical shells. The resulting dissipation in the water determines the radiation power factor, which is found to have the following value:

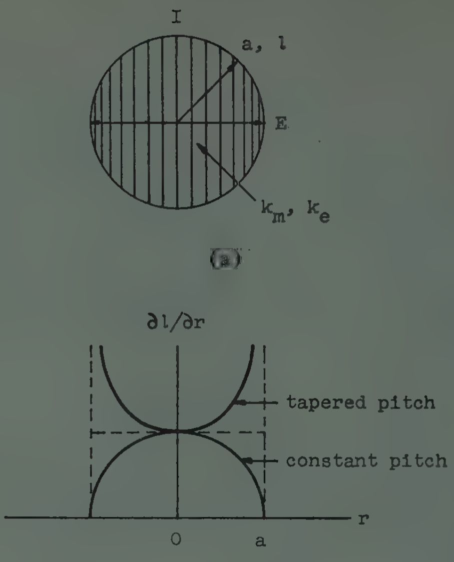
$$p = \frac{a^3}{a'\delta'^2} \frac{2}{1 + 2/k} \cdot \tag{30}$$

The principal factor is the ratio of the coil volume over another volume determined by the radome size and the skin depth in the water.

Submersion of this antenna reduces its interception area, as referred to the wave power density above the water. The free-space interception area is 3/2 of one radiancircle in free space. If this antenna is submerged to a depth several times the radome radius but much less than the skin depth in the water, its interception area is reduced to

$$\frac{3\pi}{2} a'\delta'. \tag{31}$$

This depends not on the coil size, but on the radome size and the skin depth.



(a)

(b)

Fig. 7—Self-resonant spherical coil.

X. Self-Resonant Coil

A certain form of winding on a spherical coil leads to a self-resonant inductor with the same pattern of magnetic and electric fields. By this we mean that each field inside the sphere is uniform, and outside has the field pattern of a small dipole.

Fig. 7(a) shows such a spherical coil, with its core having magnetic and electric ratios k_m and k_e. All the current in the winding is the capacitive current in the inner and outer space. The middle turns carry maximum current, while the current tapers off toward the end turns in proportion to the decreasing area per turn. The uniform fields inside require that the current density be the same as in the simple spherical inductor with onstant current (and constant axial density of current). herefore the pitch of winding must be reduced in the atio of the area per turn. This rule leads to an indefiitely large number of turns but a finite length of wire.

Fig. 7(b) shows the basis for computing the total ength of wire on a coil of tapered pitch. For reference, he lower curve gives the axial distribution of length f wire for constant pitch. In this case, the axial density atio ($\partial l/\partial r$) is proportional to the radius of the turns, ence the semicircular shape. For the self-resonant coil, he pitch is reduced in proportion to the area per turn, r the radius-squared, so the length of wire has an axial ensity inversely proportional to the radius of the urns; this is shown by the upper curve. The total length f wire is proportional to the area under these curves. ince the upper curve has twice the area of the lower urve, the self-resonant coil with tapered pitch has a otal length of wire twice as great as the simple coil with onstant pitch (assuming the same pitch in the middle).

As a measure of the varying pitch, we may write the ormulas in terms of the pitch (c) of the middle turns. he simple spherical coil of uniform axial pitch ($c=2a/n$) as its inductance given by substituting this relation in 4), also changing symbols k to k_m and k' to 1.

$$n = 2a/c \tag{32}$$

$$L = \frac{2\pi}{9} \mu_0 a n^2 \frac{3}{1+2/k_m} = \frac{8\pi}{9} \mu_0 \frac{a^3}{c^2} \frac{3}{1+2/k_m} \cdot \tag{33}$$

In the modified spherical coil with tapered pitch of inding, the same maximum current in the middle urns is associated with the same magnetic field, so it ees the same amount of inductance.

In the simple spherical coil, the axial gradient of the oltage along the winding varies with the area per turn, n the manner of Fig. 1(c), so the average gradient is of the middle gradient.

The tapered pitch changes the voltage distribution, naking the axial gradient constant, because the smaller rea per turn toward the ends is just compensated by he greater density of turns. Therefore the average radient is equal to the middle gradient and the total oltage from pole to pole is 3/2 as great for the same maxinum current in the middle turns. This voltage is

$$E = \frac{3}{2} I L \omega \tag{34}$$

n terms of L given by (33).

The capacitive current inside the coil has its maxinum value (I) in the middle turns, equal to that aused by the total voltage (E) in a cylindrical condensr of area πa^2 and spacing $2a$. This capacitance is

$$\text{cyl } C = k_e \epsilon_0 \frac{\pi a^2}{2a} = \frac{\pi}{2} k_e \epsilon_0 a. \tag{35}$$

he current in this internal capacitance is

$$I(\text{in}) = E\omega(\text{cyl } C) = E\omega\epsilon_0 \frac{\pi}{2} a k_e. \tag{36}$$

Just as the magnetic flux path outside the coil has an effective length $\frac{1}{2}$ as great as inside, the same is true of the electric flux path. But the two electric flux paths are in parallel, not in series. Therefore the total capacitive current (in the middle turns) is

$$I = E\omega\epsilon_0 \frac{\pi}{2} a(k_e + 2). \tag{37}$$

In the tapered winding, as explained with reference to Fig. 7(b), the length of wire is found to be twice as great for the same middle pitch of winding. This length is

$$l = \frac{\pi}{2} 2\pi a \frac{2a}{c} = 2\pi^2 a^2/c \tag{38}$$

$$c = 2\pi^2 a^2/l. \tag{39}$$

Substituting in (33),

$$L = \frac{2}{9\pi^3} \mu_0 \frac{l^2}{a} \frac{3}{1+2/k_m} \cdot \tag{40}$$

To determine the condition for resonance, eliminate E and I from (34) and (37), then express ω in terms of λ, and finally substitute for L from (40):

$$1 = \frac{3}{2} L\omega^2\epsilon_0 \frac{\pi}{2} a(2 + k_e) = 3\pi^3 \frac{La}{\mu_0 \lambda^2} (2 + k_e) \tag{41}$$

$$l = \frac{\lambda}{2} \sqrt{\frac{1 + 2/k_m}{1 + k_e/2}} \cdot \tag{42}$$

This shows that a coiled length of wire is self-resonant at a frequency such that its length is about $\frac{1}{2}$ wavelength, which is the well-known rule for a straight wire.

An ideal self-resonant spherical coil is conceived to be one having no energy stored inside ($k_e=0$, $k_m=\infty$). Its resonance corresponds exactly to a wire length of $\frac{1}{2}$ wavelength. Its external electric and magnetic fields store equal amounts of energy in the same pattern so they radiate equal amounts of power. They combine to radiate a wave that is circularly polarized [7].

The radiation power factors of the magnetic and electric fields, for any core properties, are

$$p_m = \frac{V/V_r}{1 + 2/k_m}; \qquad p_e = \frac{V/V_r}{1 + k_2/2} \cdot \tag{43}$$

For an air core ($k_m=k_e=1$) it appears that the electric field radiates twice as much power as the magnetic field. However, if $k_m k_e=4$, the two fields radiate equal amounts of power; this is therefore a general condition for circular polarization of the radiation. This is realizable, for example, with a dielectric core such that $k_e=4$, $k_m=1$.

This same condition is one which causes the coil to resonate with a half-wavelength of wire, as indicated by (42). In this type of coil with an air core, resonance corresponds to $l = \lambda/\sqrt{2}$.

In a self-resonant coil having $l = \lambda/2$, a dimensional relationship from (38) and (39) is

$$\lambda c = 4\pi^2 a^2 = (6\pi V)^{2/3}. \tag{44}$$

If such a coil has enough turns to be recognized as a current sheet ($c \ll 2a$), its volume is much less than the radiansphere so its radiation power factor is very small.

XI. Equivalent Spherical Coil

Any coil in a certain class has an equivalent spherical coil that may be specified on a logical basis. This class of coils includes every coil that has an air core and is made up of any number of turns wound in the same direction and located in parallel planes. The simpler cases include ordinary coils with coaxial circular turns, such as the helix of one or more layers.

A spherical coil is said to be equivalent to any coil in this class if it has the same inductance (L) and the same far field, the latter requiring the same total area of turns (A). In terms of these two properties, the equivalent spherical coil is formulated from (4) and (28) by solving for the following dimensions:

$$a = \left(\frac{\mu_0 A^2}{2\pi L}\right)^{1/3} \tag{45}$$

$$n = \left(\frac{6L^2}{\pi \mu_0^2 A}\right)^{1/3}. \tag{46}$$

The diameter ($2a$) of this equivalent spherical coil will always be less than the maximum dimension of the space occupied by the nonspherical coil.

As an example, we may take the familiar case of a long solenoid. The equivalent sphere is found to be one that has a volume slightly greater than $\frac{2}{3}$ of that of the solenoid. Therefore its diameter is greater than the solenoid diameter but much less than the solenoid length.

The equivalent spherical coil, as specified, has the same radiation power factor when regarded as a small antenna. In the case of two coils coupled in either coaxial or coplanar relationship, at a distance much greater than their radii, the two equivalent spherical coils have the same coefficient of coupling.

XII. Conclusion

The spherical coil is an interesting idealized inductor whose properties can be expressed exactly by remarkably simple formulas. Its field configurations are the simplest conceivable, as are also its formulas for coefficient of coupling and power factor of radiation. It is a basis for computing the shielding effect of a closed conducting shell (nonmagnetic). A special winding yields a corresponding simple form of self-resonant coil, whose length of wire is near $\frac{1}{2}$ wavelength at resonance. Referring to the spherical forms in general, the exact formulas for various properties yield simple rules that are approximately applicable to practical inductors such as short solenoids.

XIII. References

[1] Maxwell, J. C. *Electricity and Magnetism.* New York: Oxford University Press, 3rd ed., Vol. 2, 1892. (Spherical coil, pp. 304–308.)

[2] Wheeler, H. A., and MacDonald, W. A. "Theory and Operation of Tuned-Radio-Frequency Coupling Systems," PROCEEDINGS OF THE IRE, Vol. 19 (May, 1931), pp. 738–805. (Leakage inductance of 3-coil transformer.)

[3] Wheeler, H. A. "The Properties of Spherical Coils and Objects," Hazeltine Electronics Corp., Little Neck, N. Y., Rep. No. 1230W, August 8, 1941.

[4] ———. "Formulas for the Skin Effect," PROCEEDINGS OF THE IRE, Vol. 30 (September, 1942), pp. 412–424.

[5] Burgess, R. E. "Iron-Cored Loop Receiving Aerial," *Wireless Engineer*, Vol. 23 (June, 1946), pp. 172–178. (Spherical coil and core.)

[6] Wheeler, H. A. "Fundamental Limitations of Small Antennas," PROCEEDINGS OF THE IRE, Vol. 35 (December, 1947), pp. 1479–1484. (Radiation power factor.)

[7] ———. "A Helical Antenna for Circular Polarization," PROCEEDINGS OF THE IRE, Vol. 35 (December, 1947), pp. 1484–1488.

[8] Chu, L. J. "Physical Limitations of Omnidirectional Antennas," Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass., Tech. Rep. No. 64, May 1, 1948. (Radiation Q of space outside of sphere around electric dipole.)

[9] Harnwell, G. P. *Principles of Electricity and Electromagnetism.* New York: McGraw-Hill Book Co., Inc., 2nd ed., 1949. (Mutual inductance between coaxial coils, p. 329.)

[10] Smythe, W. R. *Static and Dynamic Electricity.* New York: McGraw-Hill Book Co., Inc., 2nd ed., 1950. (Coils on spherical forms, pp. 314–315.)

[11] Wait, J. R. "The Magnetic Dipole Antenna Immersed in a Conducting Medium," PROCEEDINGS OF THE IRE, Vol. 40 (October, 1952), pp. 1951–1952. (In a spherical cavity.)

[12] Wheeler, H. A. "Universal Skin-Effect Chart for Conducting Materials," *Electronics*, Vol. 25 (November, 1952), pp. 152–154. (Including sea water.)

[13] Wait, J. R. "The Receiving Loop with a Hollow Prolate Spheroidal Core," *Canadian Journal of Technology*, Vol. 31 (June, 1953), pp. 132–137. (Ratio of increase of induction by core.)

[14] Wheeler, H. A. "The Radiansphere Around a Small Antenna," Wheeler Laboratories, Inc., Great Neck, N. Y., Rep. No. 670, March 8, 1955. Presented at The Johns Hopkins University, Baltimore, Md., December 2, 1954. (Radiation power factor of spherical coil.)

[15] Rumsey, V. H., and Weeks, W. L. "Electrically Small, Ferrite-Loaded Loop Antennas," 1956 IRE CONVENTION RECORD, Part 1, pp. 165–170. (Radiation Q of prolate spheroid.)

[16] Wheeler, H. A. "The Spherical Coil as an Inductor, Shield, or Antenna," presented at staff meeting, Wheeler Laboratories, Inc., Great Neck, N. Y., September 25, 1956.

[17] Cruzan, O. R. "Radiation Properties of a Spherical Ferrite Antenna," Diamond Ordnance Fuze Laboratories, Washington, D. C., Tech. Rep. No. 387, October 15, 1956. (One-turn loop around spherical iron core.)

[18] Wheeler, H. A. "Fundamental Limitations of a Small VLF Antenna for Submarines," presented at National Bureau of Standards VLF Symposium, Boulder, Colo., January 23–25, 1957. IRE TRANSACTIONS ON ANTENNAS AND PROPAGATION, Vol. AP-6 (January, 1958), pp. 123–125.

Error Probabilities for Binary Symmetric Ideal Reception through Nonselective Slow Fading and Noise*

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***Summary*—One of two correlated, equal energy, equiprobable aveforms is transmitted through a channel during a given time in- rval. The signal is corrupted in the channel by slowly-varying, equency-nonselective fading and by additive, Gaussian noise. On ception, the corrupted signal is processed by an ideal receiver, hich guesses that the transmitted waveform was the one which it mputes to be *a posteriori* most probable. Expressions for the prob- ility of committing an error in making such a guess are derived for th coherent and noncoherent receivers; these are studied in de- l, and some general trends and system design considerations are ted. In an illustrative example, the results are applied to binary equency-shift keyed (FSK) systems with various pulse shapes and equency separations.**

I. INTRODUCTION

THE problem we consider here is of a restricted nature (*binary, symmetric* system; *nonselective, slow* fading); yet, despite this, the results of our analysis ll have fairly wide application to practical systems. or instance, in an illustrative example, we use a special se of one of the results to determine the effects of lse shape and frequency separation on the perform- ce of an FSK teletype system working through a atter-propagation link.

A block diagram of the communication system stud- l is shown in Fig. 1. We postpone a detailed descrip- on of the various blocks until the next section; a brief scription will suffice to give a statement of the problem.

At the transmitter, a choice is made between two rrow-band signals, $\xi_1(t)$ and $\xi_2(t)$, and one is trans- tted into the channel. We assume that both signals e zero outside of some time interval, say $0 \leq t \leq T$. ithin this interval, however, the waveshapes of the nals are essentially arbitrary: they may be simple e wave pulses of different frequencies, or they may be considerable complexity. The two signals may be correlated or they may be highly correlated. In fact, e only restrictions we place on the signals, aside from uiring finite time durations, are that they have ual probabilities of transmittal, and that they have e same energy. These are the requirements of *sym- try*, for it turns out that when they are satisfied, the probability of mistaking signal 1 for signal 2 at the receiver is the same as that of mistaking signal 2 for signal 1.

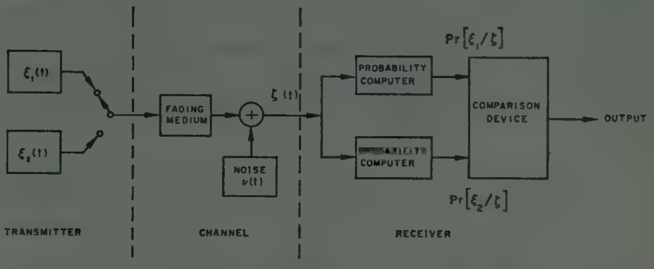

Fig. 1—The system under consideration.

The transmitted signal first passes through a linear medium which fades in a frequency-nonselective way. That is to say, the whole band of frequencies occupied by the two signals is acted on uniformly by the medium; there is no possibility of simultaneous constructive interference at one frequency and destructive interference at another. Put another way, if there is more than one transmission path, the difference of delays of any pair of paths must be much less than the reciprocal of the width of the band of frequencies occupied by the signals.

The amount of fading at any instant is, of course, a random quantity. It is assumed, however, that it does not vary appreciably for the duration of the transmitted signal, and this is what we mean by *slow* fading.

After passing through the fading medium, the transmitted signal is further perturbed by additive noise, which we assume is white, stationary, Gaussian, and statistically independent of the fading medium. The resultant signal we call $\zeta(t)$; it is the received signal.

The task of the receiver, which has available replicas of the two possible transmitted waveforms but does not know which was actually sent, is to guess, with minimum probability of error, which signal was transmitted. (We shall call a receiver which does this an *ideal* receiver.) It does this by operating on $\zeta(t)$, and it can be shown[1] that this operation consists of computing the *a posteriori* probabilities, $Pr[\xi_1/\zeta]$ and $Pr[\xi_2/\zeta]$, of the two signals, and choosing the one with the larger probability. That is, the receiver always

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[1] D. Van Meter and D. Middleton, "Modern approaches to reception in communication theory," IRE TRANS. ON INFORMATION THEORY, PGIT-4, pp. 119–145, sections 3.1 and 3.2; September, 1954.

guesses that the transmitted signal was the one which seems most probable on the basis of analysis of the received waveform.

We are mainly concerned with the evaluation of the probability of committing an error in making such a guess. In fact, the principal new result of this paper is (16), which is a general expression for this probability of error. The expression differs from previous results in that a broader class of fading phenomena (which includes, as extremes, the nonfading case and the Rayleigh-fading case) is postulated, and nonzero correlation between the two signals is allowed. The expression of course reduces to previous results in special cases, and these special cases will be pointed out.

A second goal we set is that of studying the general error probability expression in the hopes of extracting from it general trends and design rules. We shall, for example, find that the incidence even of what is normally only a moderate amount of fading markedly deteriorates the performance of the system and also makes inadvisable the use of such techniques as coherent reception and negative correlation between the two signals.

II. Detailed Model of System

Let us now, having stated the problem, go back and consider the various blocks in Fig. 1 in more detail.

A. The Signals

We have assumed that the two signals are narrow-band waveforms which are zero outside the interval $0 \leq t \leq T$. A representation of these signals which is most convenient for our purposes is the complex representation described by Woodward.[2] We represent the two signals as products of complex low-pass modulation waveforms and cisoidal carriers:

$$\begin{aligned} \xi_1(t) &= x_1(t)e^{j2\pi f_0 t} \\ \xi_2(t) &= x_2(t)e^{j2\pi f_0 t} \end{aligned} \qquad (1)$$

where f_0 is a suitably defined carrier frequency. It is the real parts of the representations in (1) which correspond to the actual physical signals; these real parts are in the form of a more familiar representation of narrow-band signals:[3]

$$\begin{aligned} \widehat{\xi}_m(t) &= \hat{x}_m(t)\cos 2\pi f_0 t - \breve{x}_m(t)\sin 2\pi f_0 t \\ &= |x_m(t)| \cos\left(2\pi f_0 t + \tan^{-1}\frac{\breve{x}_m(t)}{\hat{x}_m(t)}\right) (m = 1, 2) \end{aligned} \qquad (2)$$

where we have used "$\frown$" to denote "real part of" and "$\smile$" to denote "imaginary part of." Note that the complex modulation waveforms, $x_m(t)$, contain both amplitude and phase modulations of the carrier in the form of $|x_m(t)|$ and $\tan^{-1}\breve{x}_m(t)/\hat{x}_m(t)$, respectively. For an FSK system, as an example,

$$\begin{aligned} x_1(t) &= A(t)e^{j\pi\Delta f t}, \\ x_2(t) &= A(t)e^{-j\pi\Delta f t}, \end{aligned} \qquad (3)$$

where $A(t)$ is some (real) pulse envelope waveform and Δf is the frequency separation of the "mark" and "space" channels.

The energies of the two signals are assumed equal and may be related to the complex representations of (1) by[2]

$$E = \frac{1}{2}\int_0^T |\xi_1(t)|^2 dt = \frac{1}{2}\int_0^T |\xi_2(t)|^2 dt. \qquad (4)$$

An important quantity which relates the two signals is the complex correlation coefficient. We define it as

$$\lambda = \frac{1}{2E}\int_0^T \xi_1{}^*(t)\xi_2(t)dt = \frac{1}{2E}\int_0^T x_1{}^*(t)x_2(t)dt. \qquad (5)$$

The real part of this, $\widehat{\lambda}$, is the value of the normalized cross-correlation function of the signals at the origin. The magnitude, $|\lambda|$, is the value of the envelope of this function at the origin.[4] It is easily shown by means of the Schwarz inequality that $|\lambda| \leq 1$.

λ is a key parameter in the expressions for error probability which we shall derive; it describes the amount of "sameness" of the signals, *i.e.*, the difficulty the receiver has in telling them apart. For example, for the FSK signals described by (3), we have from (4) and (5):

$$\lambda_{\text{FSK}} = \frac{\int_0^T A^2(t)e^{-j2\pi\Delta f t}dt}{\int_0^T A^2(t)dt}. \qquad (6)$$

The cross-correlation coefficient is thus directly related to the frequency separation of the "mark" and "space" channels; for $\Delta f = 0$ we have $\lambda = 1$, the case of indistinguishable signals.

B. The Fading Medium

The model for the fading medium perhaps can be described best by indicating what happens to a signal which passes through it. Suppose $\xi_m(t) = x_m(t)e^{j2\pi f_0 t}$ is transmitted. The output of the fading model we are considering may then be represented as

$$\eta_m(t) = ax_m(t - \tau)e^{j(2\pi f_0 t - \theta)}. \qquad (7)$$

That is, the fading medium comprises a frequency non-selective path which is characterized by three quantities: a, the strength; τ, the modulation delay; and θ, the

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[2] P. M. Woodward, "Probability and Information Theory, with Applications to Radar," McGraw-Hill Book Co., Inc., New York, N. Y.; 1953.

[3] S. O. Rice, "Mathematical analysis of random noise," *Bell Sys. Tech. J.*, vol. 23, pp. 282–333; July, 1944, and vol. 24, pp. 46–157, January, 1945. [See section 3.7.] This paper also appears in "Selected Papers on Noise and Stochastic Processes," ed. N. Wax, Dover Publications, Inc., New York, N. Y.; 1954.

[4] Cf. Appendix I, letting $\tau = 0$.

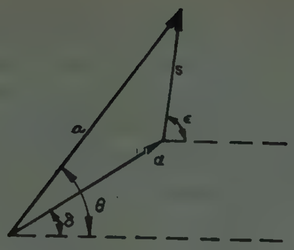

Fig. 2—Relationships among strengths and phase shifts of the fading medium.

arrier phase shift.[5] These quantities are random, and nust therefore be described in terms of probability lensity distributions. Since we have assumed slow ading, a, θ, and τ do not change appreciably during the ransmission interval. Hence, the first-order joint denity distribution, $pr[a, \theta, \tau]$, of the three path parameers will suffice to describe the fading medium.[6]

We assume here that τ is known to the receiver, either *priori* or as a result of measurements.[7] Then, assumng that a and θ are statistically independent of τ, only he distribution $pr[a, \theta]$ is necessary to complete the escription of the medium.

We further assume that the transmission path is omposed of a *fixed* component and a *random* compoent, so that (7) may be written as

$$\eta_m(t) = x_m(t - \tau)\left[\alpha e^{-i\delta} + s e^{-i\epsilon}\right]e^{i2\pi f_0 t}; \tag{8}$$

and δ are the strength and phase shift of the fixed comonent, respectively, while s and ϵ are the same quantiies for the random component. The relationships among he quantities α, δ, s, ϵ, a, and θ are depicted vectorially Fig. 2.

For the joint density distribution of s and ϵ we postuate:

$$pr[s, \epsilon] = \begin{cases} \dfrac{s}{2\pi\sigma^2} \exp\left[-\dfrac{s^2}{2\sigma^2}\right] & \begin{Bmatrix} 0 \le s \le \infty \\ 0 \le \epsilon \le 2\pi \end{Bmatrix} \\ 0 & \text{elsewhere} \end{cases} \tag{9}$$

That is, s and ϵ are independent quantities, the first being Rayleigh distributed with mean-square $2\sigma^2$, and the second uniformly distributed over the interval $(0, 2\pi)$. It is easily shown[8] that the joint distribution of the length and angle of the sum of the fixed vector (α, δ) and the random vector (s, ϵ) described by (9) is

$$pr[a, \theta] = \begin{cases} \dfrac{a}{2\pi\sigma^2} \exp\left[-\dfrac{a^2 + \alpha^2 - 2\alpha a \cos(\theta - \delta)}{2\sigma^2}\right] & \\ & \begin{Bmatrix} 0 \le a \le \infty \\ 0 \le \theta - \delta \le 2\pi \end{Bmatrix} \\ 0 & \text{elsewhere} \end{cases} \tag{10}$$

The marginal distribution of the strength a, obtained by integrating (10) over θ, is given by

$$pr[a] = \begin{cases} \dfrac{a}{\sigma^2} \exp\left[-\dfrac{a^2 + \alpha^2}{2\sigma^2}\right] I_0\left(\dfrac{\alpha a}{\sigma^2}\right) & 0 \le a \le \infty, \\ 0 & a < 0 \end{cases} \tag{11}$$

where I_0 is the *zero*th-order modified Bessel function of the first kind. Rice[8] gives (normalized) curves of this distribution with parameter $\gamma = \alpha/\sigma$; these curves are reproduced in Fig. 3. Curves of the marginal distribution $pr[\theta]$, given by Middleton,[9] are reproduced with modifications[9] in Fig. 4. As is to be expected, the smaller the random component of the transmission path is compared to the fixed component ($\sigma \rightarrow 0$), the more sharply the a and θ distributions cluster around the values α and δ, respectively.

The joint distribution of (10) appears to be a good description of many "single"-path[10] propagation conditions which are encountered. For ionospheric radio links above the muf[11] and for tropospheric radio links,[12] experimental results indicate that the fading is Rayleigh distributed and quasi-stationary for time intervals of the order of minutes; this corresponds to letting $\alpha = 0$ in (10), and considering that σ changes slowly over many minutes (*very* much longer than the transmission interval, T). For ionospheric radio links below the muf there is evidence that both fixed and random components are present ($\alpha \neq 0$, $\sigma \neq 0$),[13,14] although the physi-

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[5] Considering the modulation delay and carrier phase shift of the ath as independent entities is a convenient device and is, moreover, stifiable on a physical basis: most nonselective transmission paths *g.*, nonselective scatter paths) which fluctuate randomly do so ecause of the alternate constructive and destructive interference a large number of "subpaths" whose delays differ from one anher by amounts which are small compared to the reciprocal of the ansmission bandwidth. As far as the modulation is concerned, all these subpaths have very nearly the same delay; this delay we ll τ. As far as the carrier is concerned, however, the subpaths have lays which are greatly different. Thus, small fluctuations in the bpath delays will not noticeably affect the modulation delay, but ay greatly change the carrier phase. Therefore, we may speak of anges in θ for a "fixed" τ. For further discussion of this point, see otnotes 15 and 16.

[6] Fast fading has been considered in a special case (no fixed comnent) by R. Price, "Optimum detection of random signals in ise, with application to scatter-multipath communication," IRE RANS. ON INFORMATION THEORY, vol. IT-2, pp. 125–135; December, 56. Part II of Price's paper, to be published, contains error probility analyses of the ideal receiver in this special case. Also see R. ice and P. E. Green, Jr., "A communication technique for multith channels," PROC. IRE, vol. 46, pp. 555–570; March, 1958.

[7] G. L. Turin, "On the estimation in the presence of noise of the pulse response of a random, linear filter," IRE TRANS. ON INRMATION THEORY, vol. IT-3, pp. 5–10; March, 1957.

[8] S. O. Rice, *op. cit.*, sec. 3.10.

[9] D. Middleton, "Some general results in the theory of noise through non-linear devices," *Quart. Appl. Math.*, vol. 5, pp. 445–498; Fig. 4(a); January, 1948. L. A. Rondinelli has called the author's attention to inaccuracies in Middleton's curves; these have been corrected in Fig. 4.

[10] However, a single path may consist of many subpaths (see footnote 5); hence, the quotation marks.

[11] R. A. Silverman and M. Balser, "Statistics of electromagnetic radiation scattered by a turbulent medium," *Phys. Rev.*, vol. 96, pp. 560–563; November, 1954.

[12] K. Bullington, W. J. Inkster, and A. L. Durkee, "Results of propagation tests at 505 mc and 4090 mc on beyond-horizon paths," PROC. IRE, vol. 43, pp. 1306–1316; October, 1955.

[13] R. W. E. McNicol, "The fading of radio waves on medium and high frequencies," *Proc. IEE*, vol. 96, pt. 3, pp. 517–524; November, 1949. Also see D. G. Brennan and M. L. Phillips, "Phase and Amplitude Variability in Medium-Frequency Ionospheric Transmission," M.I.T., Lincoln Lab., Lexington, Mass., Tech. Rep. 93; September 16, 1957.

[14] R. Price, "The autocorrelogram of a complete carrier wave received over the ionosphere at oblique incidence," PROC. IRE, vol. 45, pp. 879–880; June, 1957.

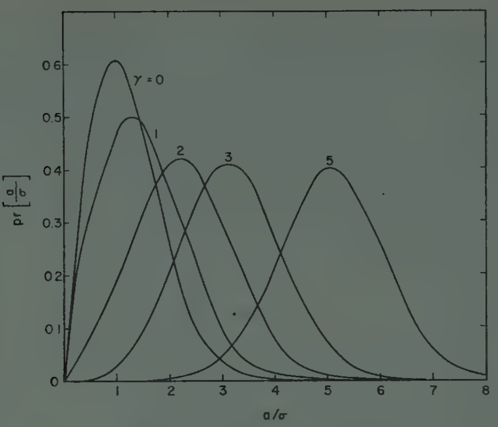

Fig. 3—Normalized marginal distribution of a.

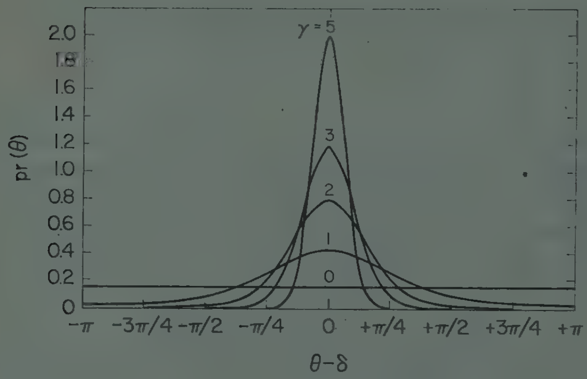

Fig. 4—Marginal distribution of θ.

cal nature of these is not completely clear at present; the two components are often called, respectively, the specular and the scatter components.

The three parameters, α, σ, and δ of the distribution (10) have useful interpretations. α is the strength of the fixed component and $\sqrt{2}\sigma$ is the rms strength of the random component; if average power P is transmitted, the received average power is $(\alpha^2+2\sigma^2)P$.[8] We define the ratio $\gamma=\alpha/\sigma$; γ^2 is thus twice the ratio of the average power received via the fixed component to the average power received via the random component. δ is the mean or expected phase shift of the path.

C. The Additive Noise

We assume that the additive noise is Gaussian, statistically stationary, independent of the fading medium, and has a flat (single-ended) power density, N_0 (watts /cps), at least over the transmission bandwidth.

D. The Receiver

It is assumed that the receiver has a knowledge of the time base and, in the coherent case considered below, of the phase base of the transmitter. In previous work[15,16] it was shown that the basic operation performed by the ideal receiver in computing the *a posteriori* probabilities, $Pr[\xi_1/\zeta]$ and $Pr[\xi_2/\zeta]$ is that of cross-correlation of the received signal with the stored replicas of each of the two transmitted signals. In complex notation, the basic cross-correlation functions are

$$\begin{aligned}\rho_m(u) &= \frac{1}{2}\int \xi^*(t)\zeta_m(t-u)dt \\ &= \left[\frac{1}{2}\int z^*(t)x_m(t-u)dt\right]e^{-i2\pi f_0 u} \\ &= r_m(u)e^{-i2\pi f_0 u} \qquad (m = 1, 2) \qquad (12)\end{aligned}$$

where $\zeta(t)=z(t)e^{i2\pi f_0 t}$ is the complex representation of the received signal, the asterisk denotes "complex conjugate," and the integral is taken over all intervals of nonzero integrand. Note that $\rho_m(u)$ is, like $\xi_1(t)$ and $\xi_2(t)$ of (1), a product of a complex low-pass modulation function,

$$r_m(u) = \frac{1}{2}\int z^*(t)x_m(t-u)dt, \qquad (13)$$

and a cisoidal carrier of frequency f_0. That is, $\rho_m(u)$ is an amplitude and phase modulated waveform with carrier frequency f_0. It can be shown,[17] using the usual narrow-band approximations, that the real part of $\rho_m(u)$ is the cross-correlation function of the physical signals, $\hat{\zeta}(t)$ and $\hat{\xi}_m(t)$, and the magnitude of $\rho_m(u)$ is the envelope of this physical cross-correlation function. That is,

$$\hat{\rho}_m(u) = \text{Re}\left\{r_m(u)e^{-i2\pi f_0 u}\right\} = \int \hat{\zeta}(t)\hat{\xi}_m(t-u)dt \qquad (14a)$$

and

$$|\rho_m(u)| = |r_m(u)| = env\left[\int \hat{\zeta}(t)\hat{\xi}_m(t-u)dt\right]. \qquad (14b)$$

In the previous work just referred to, it is shown that for the binary, symmetric, "single"-path case we are considering, the ideal receiver decides whether $Pr[\xi_1/\zeta]$ or $Pr[\xi_2/\zeta]$ is the larger by performing the following operations.

1) *Coherent Receiver:* When the mean path phase, δ, is known to the receiver, it makes its decision according as[18]

$$\frac{\sigma^2}{N_0}\,|r_m(\tau)|^2 + \alpha\,\text{Re}\,\{r_m(\tau)e^{-i\delta}\} \qquad (15)$$

is larger for $m=1$ or $m=2$. Notice from (14b) that the first term of (15) contains the envelope of the cross-

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[15] G. L. Turin, "Communication through noisy, random-multipath channels," 1956 IRE NATIONAL CONVENTION RECORD, pt. 4, pp. 154–166; March, 1956.

[16] G. L. Turin, "Communication Through Noisy, Random-Multipath Channels," M.I.T., Lincoln Lab., Lexington, Mass., Tech. Rep. 116; May 14, 1956. This is a more detailed report than footnote 15.

[17] See Appendix I.

[18] See (34) of footnote 15, in which let $L=1$, $E_1=E_2$ and then note that Λ_m is a monotone increasing function of

$$\frac{\sigma_1^2}{N_0}\,|g_{m1}|^2 + 2\alpha_1\,\text{Re}\,[g_{m1}e^{-j\delta_1}].$$

Identify σ_1, α_1, δ_1 and g_{m1} with σ, α, δ, and $2r_m(\tau)$ of the present paper.

correlation of the received signal and the mth stored signal, evaluated at delay τ. Similarly, by comparison with (14a), one can identify the factor $\operatorname{Re}\{r_m(\tau)e^{-i\delta}\}$ of the second term of (15) as the cross correlation of the received signal and the mth stored signal, evaluated at modulation delay τ, in phase δ.[19] Several methods of actually obtaining these quantities are reviewed in Appendix II.

Note from (15) that in addition to knowing δ, the coherent receiver generally must know the channel-parameter ratio $\sigma^2/\alpha N_0$.

2) *Noncoherent Receiver:* If the receiver does not know the value of δ (or equivalently does not know the transmitter phase), it makes its decision on the basis of samples of cross-correlation envelopes alone. That is, it decides that signal 1 or signal 2 has been sent according as $|r_m(\tau)|$ is greater for $m=1$ or $m=2$.[20] Note that in addition to not knowing δ, a noncoherent receiver need not know $\sigma^2/\alpha N_0$ either, in order to make a decision; this is a great practical advantage over a coherent receiver, which must know both quantities.

III. Probability of Error

We are now in a position to derive expressions for the probability that the receiver makes an error in its decision. The details of the derivations are left to the Appendices; here we merely set down the expressions and special cases of these, and then consider an illustrative application to a practical system.

The generic form of the probability of error, P_e, for both the coherent and noncoherent cases, is:[21]

$$P_e = Q(ac, bc) - \frac{1}{2}\left[1 + \frac{\mu\sqrt{1-|\lambda|^2}}{\sqrt{1-\mu^2|\lambda|^2}}\right] e^{-(a^2+b^2)c^2/2} I_0(abc^2), \quad (16)$$

where we have

$$Q(x, y) = \int_y^\infty e^{-(t^2+x^2)/2} I_0(xt)\,dt, \quad (17)$$

$$\mu = \frac{\beta}{\beta + 2}, \quad (18)$$

$$\beta = \frac{2\sigma^2 E}{N_0}, \qquad \gamma = \frac{\alpha}{\sigma}, \quad (19)$$

and λ is given by (5). The Q-function, $Q(x, y)$, has been tabulated by Marcum.[22] The quantities a, b, and c of (16) differ for the coherent and noncoherent cases.

A. Coherent Receiver

For this case we have[23]

$$a = 1 - \frac{\mu\sqrt{1-|\lambda|^2}}{\sqrt{1-\mu^2|\lambda|^2}}, \quad (20)$$

$$b = 1 + \frac{\mu\sqrt{1-|\lambda|^2}}{\sqrt{1-\mu^2|\lambda|^2}}, \quad (21)$$

$$c = \sqrt{\frac{\beta\gamma^2[\beta(1-|\lambda|^2) + 2(1-\hat{\lambda})]}{4\beta^2(1-|\lambda|^2)}}. \quad (22)$$

Two special cases of interest are worth noting. The first is for $\sigma=0(\gamma=\infty)$, or a fixed path of known phase. Here $\beta=0$ and $\mu=0$, while

$$\beta\gamma^2 = \frac{2\sigma^2 E}{N_0}\cdot\frac{\alpha^2}{\sigma^2} = \frac{2\alpha^2 E}{N_0}$$

stays nonzero and finite. In order to evaluate P_e in this case, we note the following asymptotic expressions:

$$I_0(x) \sim \frac{e^x}{\sqrt{2\pi x}} \quad \text{for large } x, \quad (23)$$

$$Q(x, y) \sim \frac{1}{2}\left[1 - \operatorname{erf}\left(\frac{y-x}{\sqrt{2}}\right)\right] \text{ for large } x \text{ and } y,^{24} \quad (24)$$

where

$$\operatorname{erf}(z) = \frac{2}{\sqrt{\pi}}\int_0^z e^{-t^2}dt. \quad (25)$$

Hence for $\sigma\to 0$,

$$P_e \sim \frac{1}{2}\left[1 - \operatorname{erf}\left\{\frac{(b-a)c}{\sqrt{2}}\right\}\right] - \frac{1}{2}\,\frac{e^{-(b-a)^2c^2/2}}{\sqrt{2\pi abc^2}}. \quad (26)$$

But for $\sigma\to 0$,

$$(b-a)c \to \sqrt{\frac{\beta\gamma^2(1-\hat{\lambda})}{2}} \quad \text{and} \quad c\to\infty. \quad (27)$$

So, finally,

$$P_e = \frac{1}{2}\left[1 - \operatorname{erf}\left(\sqrt{\frac{\alpha^2 E(1-\hat{\lambda})}{2N_0}}\right)\right]. \quad (28)$$

This result agrees with previously derived expressions.[25]

The other special case of interest is that for $\alpha=0(\gamma=0)$, or Rayleigh-distributed fading [see (10) with $\alpha=0$]. Here the criteria for coherent and noncoherent detection become the same, *i.e.*, a comparison of correlation *envelopes*. Putting $c=0$ in (16) and noting that $Q(x, 0)=1$, we have for this case

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[19] Again we make use of the vast difference in the period of the highest modulation frequency in $\xi_m(t)$ [and hence in $\rho_m(u)$] and the carrier period to justify speaking of any carrier phase of $\rho_m(u)$ for a given modulation delay.

[20] See (26) of footnote 15 in which let $L=1$, $E_1=E_2$, and then note that Λ'_m is a monotone increasing function of $|g_{m1}|$.

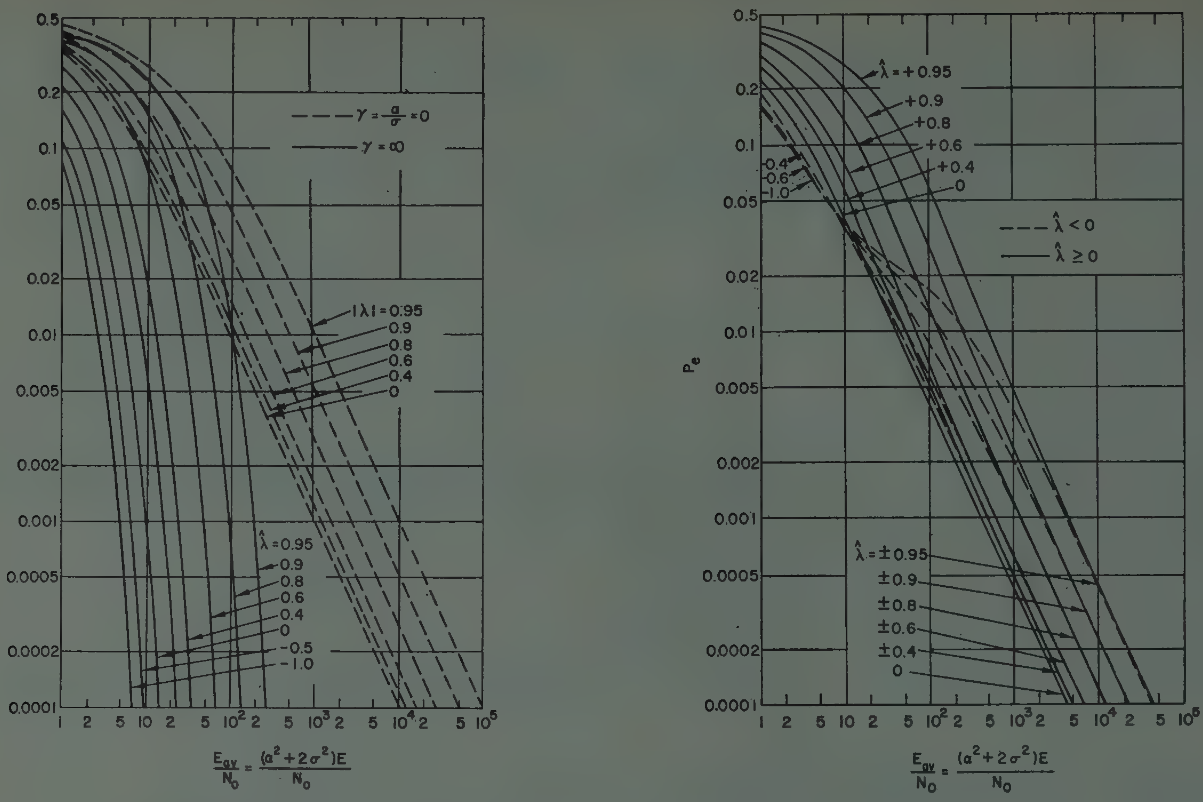
[21] Note that the a in (16) is not the same as that in (7).

[22] J. I., Marcum, "Table of Q Functions," Rand Corp., Santa Monica, Calif., Rep. RM-339; January 1, 1950. Machine computation using a series representation for Q was used in the present paper, however.

[23] See Appendix III.

[24] C. W. Helstrom, "The resolution of signals in white, Gaussian noise," Proc. IRE, vol. 43, pp. 1111–1118, eq. (60); September, 1955.

[25] C. W. Helstrom, *op. cit.*, (13). Also see (55) of footnote 15.



(a) (b)

Fig. 5—Probability of error, coherent receiver (a) $\gamma=0$ and $\gamma=\infty$, (b) $\gamma=2$.

$$P_e = \frac{1}{2}\left[1 - \frac{\mu\sqrt{1-|\lambda|^2}}{\sqrt{1-\mu^2|\lambda|^2}}\right]. \tag{29}$$

This agrees with a previously given result.[26]

The difference of the performances with increasing signal-to-noise ratio of the two special cases of the ideal coherent receiver considered above is striking. Consider (28) as we let the ratio E/N_0, increase to large values. Then[27]

$$P_e \sim \frac{1}{\sqrt{2\pi\frac{\alpha^2 E(1-\hat{\lambda})}{N_0}}}\, e^{-\alpha^2 E(1-\hat{\lambda})/2N_0}. \tag{30}$$

Thus, when $\sigma=0$, P_e decreases approximately exponentially with E/N_0 for large E/N_0.

Now, as a comparison, let us consider the behavior of P_e for large E/N_0 when $\alpha=0$. Using (18), let us first rewrite (29) as

$$P_e = \frac{\sqrt{1+K}-1}{2\sqrt{1+K}}, \tag{31}$$

where

$$K = \frac{4(\beta+1)}{\beta^2(1-|\lambda|^2)}. \tag{32}$$

As $(E/N_0)\to\infty$, we have $\beta\to\infty$, and

$$K \to \frac{4}{\beta(1-|\lambda|^2)}.$$

Further,

$$P_e \to \frac{1}{4}K \to \frac{1}{\beta(1-|\lambda|^2)} = \frac{1}{\frac{2\sigma^2 E(1-|\lambda|^2)}{N_0}}. \tag{33}$$

Thus, for $\alpha=0$, P_e decreases only *inversely* with E/N_0 for large E/N_0. This is a far cry from the exponential behavior shown by (30) for the fixed-path case!

P_e is shown in Fig. 5 as a function of

$$\frac{E_{av}}{N_0} = \frac{(\alpha^2+2\sigma^2)E}{N_0},$$

which, as we have seen, is the ratio of the average received energy to the noise power density.[28] Three sets of curves are given: $\gamma=0(\alpha=0)$, $\gamma=2(\alpha=2\sigma)$, and $\gamma=\infty(\sigma=0)$. The family parameter in the first set is $|\lambda|$; $\hat{\lambda}$ does not appear explicitly [*cf.* (29)]. In the second set, we let $\tilde{\lambda}=0$ since it can be shown[29] that this value minimizes P_e with respect to $\tilde{\lambda}$; hence, for $\gamma=2$ we set $|\lambda|^2=\hat{\lambda}^2$. The parameter of the third set is $\hat{\lambda}$, since $\tilde{\lambda}$ does not appear in (28).

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[26] See (57) and (58) of footnote 15. For the special case of $|\lambda|=0$, also see M. Masonson, "Binary transmission through noise and fading," 1957 IRE NATIONAL CONVENTION RECORD, pt. 2, pp. 69–82, (20), in which identify Masonson's 2μ with β of the present paper.

[27] W. Magnus and F. Oberhettinger, "Formulas and Theorems for the Functions of Mathematical Physics," Cheslea Publishing Co., New York, N. Y., p. 96; 1954.

[28] The quantity E_{av}/N_0 is related to the average received signal-to-noise *power* ratio in the band of either signal in the following way. Let B_m be the *noise* bandwidth of the mth signal ($m=1, 2$), or equivalently of its matched filter (see Appendix II); then $B_m N_0 = N_m$ is the noise power in the mth band. $E_{av}/T = P_{av}$ is the average power of the received signal. Thus, $P_{av}/N_m = (1/B_mT)(E_{av}/N_0)$ is the average received signal-to-noise power ratio *in the mth band* when signal m is transmitted.

We have seen how greatly deteriorated the large-E_{av}/N_0 performance of a Rayleigh-fading channel ($\gamma=0$) is, compared to that of a nonfading channel; this is well illustrated in Fig. 5(a). Note from Fig. 5(b) that the deterioration is almost as bad for the case $\gamma=2$. Since $r=2$ apparently does not correspond to an abnormally large amount of fading in actual physical cases when both fixed and random path components are present (*e.g.*, in below-the-muf ionospheric transmission[18]), we may state as a rough general conclusion that the incidence of fading is accompanied by markedly deteriorated performance; that is, in those physical situations where fading is generally encountered, we may expect relatively high error rates. This conclusion is not so surprising when one considers the catastrophic effect of *deep* fades on the error probability. In a deep fade, the signal for all practical purposes disappears, so that the error probability in this condition is near 1/2. Thus, even if such deep fades are fairly improbable, the contribution of deep-fade errors to the over-all error probability still may well be considerable, and cause a very much larger error probability than if, as in the nonfading case, deep fades did not exist at all.

Note from Fig. 5 that for $\gamma=\infty$, $\lambda=-1$ yields the minimum value of P_e for all signal-to-noise ratios. Now, $\lambda=-1$ obtains when $\xi_1(t)=-\xi_2(t)$ [see (4) and (5)], that is, when the two signals are the same except for a 180° difference in carrier phase. Thus, as we should expect for a coherent receiver and a fixed path, we can make use of phase differences between the signals in the reception process.

At the opposite extreme, when $\gamma=0$, $\lambda=0$ is optimum for all E/N_0. In this case, the phase is completely randomized by the fading medium, so phase relationships between the two signals cannot be exploited in the reception process; uncorrelated signals are best.

For intermediate values of γ the optimum value of $\hat{\lambda}$ is a function of signal-to-noise ratio. In general [see, *e.g.*, Fig. 5(b)], $\lambda_{opt}=-1$ for small E_{av}/N_0 (roughly, when noise is the more important of the two channel disturbances), while $\lambda_{opt}=0$ for large E_{av}/N_0 (roughly, when fading is the more important disturbance). There is a transition region for which $0<\lambda_{opt}<-1$.

Note, however, that even for $\gamma=2$, the optimum value of λ is essentially zero in the region of interest, $P_e\leq 0.01$. Now, for ionospheric and tropospheric scatter transmission ($\gamma=0$), the fading is of course always more severe than that for $\gamma=2$. For below-the-muf ionospheric transmission, as we have noted, empirical data[18] indicate that fading is usually more severe than that for $\gamma=2$. We are thus led to the following loose generalization: when fading does exist, uncorrelated signals are normally optimum in the operating region of interest. In this case, the phase coherence of the fixed component, even when dominant, cannot be exploited by making $\hat{\lambda}$ negative; in particular, setting $\hat{\lambda}=-1$ would be almost as bad as setting $\lambda=+1$ (for which $P_e\equiv\frac{1}{2}$).

B. Noncoherent Receiver

For this case we have[30]

$$a=\sqrt{1-\frac{\sqrt{(1-|\lambda|^2)(1-\mu^2|\lambda|^2)}}{1-\mu|\lambda|^2}}, \tag{34}$$

$$b=\sqrt{1+\frac{\sqrt{(1-|\lambda|^2)(1-\mu^2|\lambda|^2)}}{1-\mu|\lambda|^2}}, \tag{35}$$

$$c=\sqrt{\frac{\mu\gamma^2}{2}\cdot\frac{1-\mu|\lambda|^2}{1-\mu^2|\lambda|^2}}. \tag{36}$$

Note that here $a^2+b^2=2$.

Again the two special cases $\sigma=0$ and $\alpha=0$ of interest. For the first of these, *i.e.*, for a fixed path and phase-noncoherent receiver, P_e reduces to

$$P_e=Q\left(\sqrt{\frac{\beta\gamma^2}{4}(1-\sqrt{1-|\lambda|^2})},\ \sqrt{\frac{\beta\gamma^2}{4}(1+\sqrt{1-|\lambda|^2})}\right) - \frac{1}{2}e^{-(\beta\gamma^2)/4}I_0\left(\frac{\beta\gamma^2}{4}|\lambda|\right). \tag{37}$$

This expression checks with one derived by Helstrom.[31] On letting $(E/N_0)\rightarrow\infty$ in (37), and using (24) and the asymptotic expression for erf(x), it is easy to show that for a noncoherent receiver, as for a coherent receiver, P_e drops off approximately exponentially with increasing E/N_0 for $\sigma=0$.

When $\alpha=0$, the noncoherent receiver and the coherent receiver are identical, and as we should expect, P_e reduces to the coherent-receiver expression for the $\alpha=0$ case, (29).

Another special case of interest is that for $|\lambda|=0$. In this limit, we have $a=0$, $b=\sqrt{2}$, and $c=\sqrt{\mu\gamma^2/2}$. Since $Q(0,y)=e^{-y^2/2}$, then,

$$P_e=\frac{1}{\beta+2}e^{-(\beta\gamma^2)/2(\beta+2)}. \tag{38}$$

This checks with a previous result.[32]

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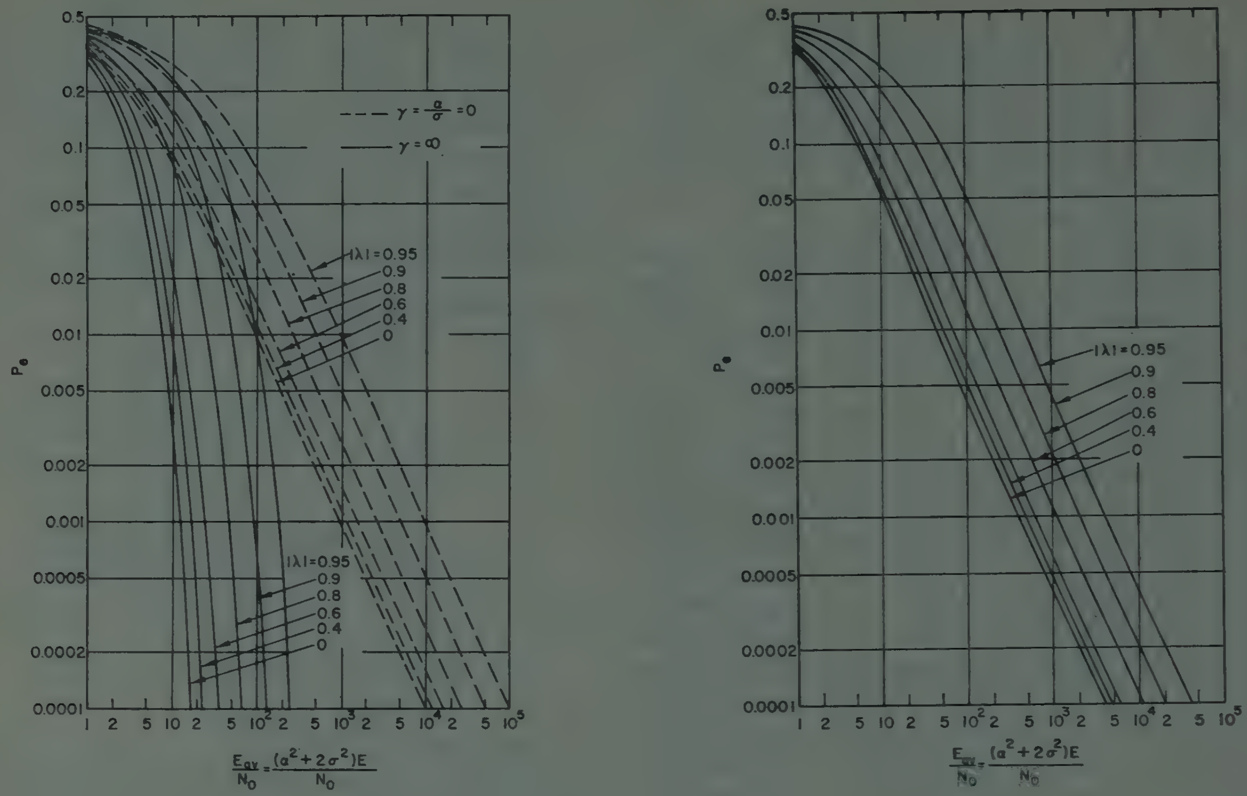
[29] See chapter V of footnote 16.

[30] See Appendix IV.

[31] C. W. Helstrom, *op. cit.*, (37). Note that Helstrom uses the symbol λ in two senses: in reference to a coherent receiver, it stands for our $\hat{\lambda}$; in reference to a noncoherent receiver, it stands for our $|\lambda|$.

[32] See (36) of footnote 15.



(a) (b)

Fig. 6—Probability of error, noncoherent receiver (a) $\gamma=0$ and $\gamma=\infty$, (b) $\gamma=2$.

Families of curves of P_e for noncoherent reception for $\gamma=0, \gamma=2$, and $\gamma=\infty$ are given in Fig. 6, with $|\lambda|$ as a parameter in each family. Note that $|\lambda|=0$ (uncorrelated signals) is optimum for all γ and all E/N_0. A comparison of Fig. 6 with Fig. 5 will show that for each γ the curves of P_e for the coherent and noncoherent cases are approximately coincident for large E_{av}/N_0, with the approximation getting better for large $|\lambda|$.

For comparison purposes, various curves from Fig. 5 and Fig. 6 are replotted in Fig. 7. Inspection of Fig. 7 reveals a generalization which is corollary to our previous generalization about λ_{opt}: when fading does exist, normally little is gained by the use of a coherent receiver (see curves 1, 2, and 3 in Fig. 7). Of course, for a a fixed path, the use of a coherent receiver can result in up to a 4-db improvement over a noncoherent receiver (see curves 4, 5, and 6 in Fig. 7). But the performance of a noncoherent receiver for $\gamma=\infty$ is already so excellent that the extra power advantage may not be needed.

One is led, on the basis of our discussions of Fig. 5–Fig. 7, to the practical conclusion that a system which is to operate through *both* fixed and nonselectively fading paths will be essentially optimal if it is designed to use uncorrelated signals and noncoherent reception exclusively. The use of noncoherent reception also has the benefit, as seen, of obviating the need for knowledge of the channel parameters δ and $\sigma^2/\alpha N_0$ at the receiver.

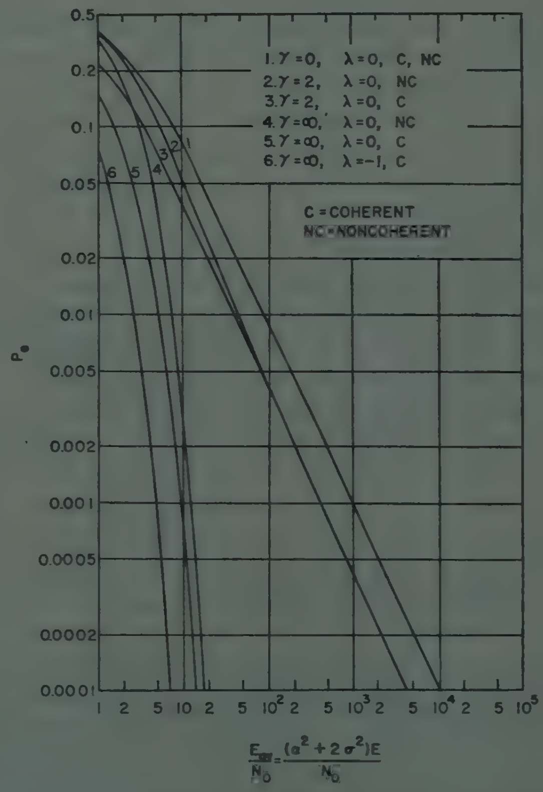


Fig. 7—Comparison of probability of error curves for several important cases.

IV. AN EXAMPLE

To illustrate the application of the previous results to a practical system, we consider the FSK system characterized by the modulation waveforms of (3). These waveforms are sine wave pulses, both having the pulse shape $A(t)$, but one having carrier frequency $f_0-(\Delta f/2)$ and the other having carrier frequency $f_0+(\Delta f/2)$. The complex correlation coefficient of these waveforms is given by (6). We shall consider only the noncoherent case, so we require only $|\lambda|$. We now derive expressions for the functional dependence of $|\lambda|$ on the frequency separation, Δf, for some particular pulse shapes.

A. Rectangular Pulses

For a rectangular pulse, $A(t)$ is

$$A(t) = \begin{cases} 1 & 0 \le t \le T \\ 0 & \text{elsewhere}, \end{cases} \tag{39}$$

$|\lambda|$ is then, from (6),

$$|\lambda| = \left| \frac{\sin \pi \Delta f T}{\pi \Delta f T} \right|. \tag{40}$$

B. Gaussian Pulses

Here we take

$$A(t) = \begin{cases} e^{-a^2(t-T/2)} & 0 \le t \le T \\ 0 & \text{elsewhere}. \end{cases} \tag{41}$$

If a sufficient amount of the tails of the Gaussian pulse are included in the interval (O, T), *i.e.*, if say $(a^2T^2/4)>3$, then the limits on the integrals in (6) and the tails of $A(t)$ may for approximate computational purposes be extended to $(-\infty, \infty)$, and $|\lambda|$ is easily evaluated as

$$|\lambda| = e^{-0.692(\Delta f/W)^2}. \tag{42}$$

Here $W=0.375a$ is the half-power bandwidth of the spectrum of the infinitely extended Gaussian pulse, and very nearly the half-power bandwidth of the finite duration pulse.

C. Exponential Pulses

Now we consider

$$A(t) = \begin{cases} e^{-\pi W t} & 0 \le t \le T \\ 0 & \text{elsewhere}. \end{cases} \tag{43}$$

Again, if a sufficient amount of the tail of $A(t)$ is included in (O, T) $[WT>1$, say$]$ then we may infinitely extend the limits in (6) and the right tail of $A(t)$ to obtain as a good approximation

$$|\lambda| = \frac{1}{\sqrt{1+\left(\frac{\Delta f}{W}\right)^2}}. \tag{44}$$

W is very nearly the half-power bandwidth of the spectrum of $A(t)$.

D. Rectangular Spectra

Finally let us evaluate $|\lambda|$ for an $A(t)$ of the form

$$A(t) = \begin{cases} \dfrac{\sin \pi W(t-T/2)}{\pi W(t-T/2)} & 0 \le t \le T/2. \\ 0 & \text{elsewhere} \end{cases} \tag{45}$$

If $(WT/2)>3$, say, we may again extend the limits on the integrals of (6) and the tails of $A(t)$, and write

$$|\lambda| = \begin{cases} 1 - \dfrac{\Delta f}{W} & \Delta f \le W \\ 0 & \Delta f > W. \end{cases} \tag{46}$$

The two signals, $\hat{\xi}_1(t)$ and $\hat{\xi}_2(t)$, have very nearly rectangular spectra of bandwidth W centered on $f_0-(\Delta f/2)$ and $f_0+(\Delta f/2)$, respectively. The spectra become more and more rectangular as $TW\rightarrow\infty$.

The four correlation coefficients derived above are plotted as functions of Δf in Fig. 8. Using these curves in conjunction with the curves of Fig. 5 and Fig. 6 one may answer such questions as, "How much must transmitter power be increased in order to keep the same error rate for a given reduction in frequency separation (or over-all bandwidth)?" For example, consider a system which operates through a scatter-propagation link ($\gamma=0$). From Fig. 5 or Fig. 6 and Fig. 8 one can plot the required E_{av}/N_0 as a function of frequency separation for any given value of P_e. This is done in Fig. 9 for $P_e=0.01$, where the reference value (0 db) of E_{av}/N_0 is that for $|\lambda|=0$ ($\Delta f=\infty$). From this figure we note, for instance, that in the case of rectangular spectra a change from adjacent but nonoverlapping bands ($\Delta f/W=1$) to bands which overlap each other by 50 per cent ($\Delta f/W=\frac{1}{2}$), requires a 1.2 db increase in transmitter power to maintain a 1 per cent error probability; that is, a 25 per cent reduction in over-all bandwidth in this case requires a 30 per cent increase in power.

We may also compare the performances of systems with different pulse shapes. Suppose, for example, we wish to compare two FSK systems which are to work through a scatter link: one with rectangular pulses, the other with Gaussian pulses. For a fair comparison we assume equal time durations of the different pulses, so as to have equal information rates. That is, letting the Gaussian pulse duration, T_g, extend to say the 5 per cent points on the tails ($a^2T_g^2/4=3$ in (41)), and equating T_g to the duration of the rectangular pulse, T_r, we get

$$a^2 = 12 \cdot \frac{1}{T_r^2}. \tag{47}$$

In terms of the half-power bandwidths of the pulses

$$W_g = 0.375a, \qquad W_r = \frac{0.88}{T_r},$$

we have

$$W_g \cong 1.47 W_r. \tag{48}$$

We also equate the energies (and, hence, average powers) of the two types of pulses [*cf.* (4)]:

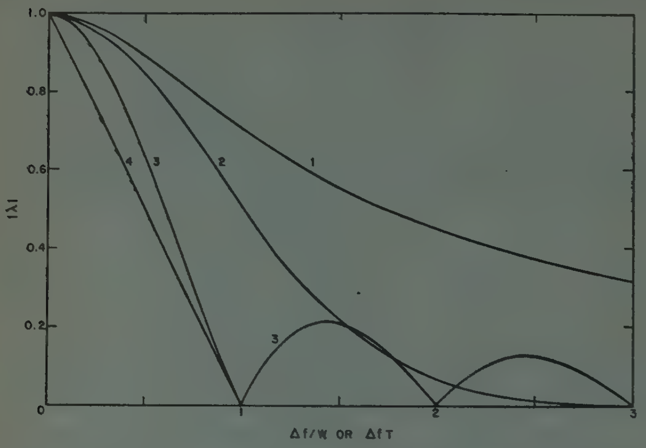


Fig. 8—The magnitude, |λ|, of FSK correlation coefficients for several pulse shapes. 1) Exponential pulses: half-power bandwidth, *W*. 2) Gaussian pulses: half-power bandwidth, *W*. 3) Rectangular pulses: duration, *T*. 4) Rectangular spectra: bandwidth, *W*.

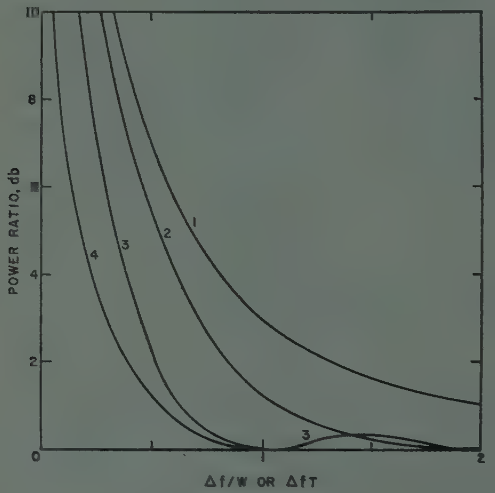


Fig. 9—The effect of FSK frequency separation, Δ*f*, on power required for one per cent error probability, $\gamma=0$ (0 db corresponds to $\Delta f=\infty$). 1) Exponential pulses: half-power bandwidth, *W*. 2) Gaussian pulses: half-power bandwidth, *W*. 3) Rectangular pulses: duration, *T*. 4) Rectangular spectra: bandwidth, *W*.

$$\frac{1}{2}\int_{-T_g/2}^{T_g/2} k^2 e^{-2a^2t^2}dt = \frac{1}{2}\int_{-T_r/2}^{T_r/2} dt. \tag{49}$$

Here k is the height of the peak of the Gaussian pulse relative to that of the rectangular pulse. Using the approximation of extending the limits of the left-hand integral to $(-\infty, \infty)$, and using (47), we get $k^2=2.76$; that is, 2.76 times as much peak power must be used in the Gaussian case for the same average power. This situation is depicted in Fig. 10.

Now suppose that at the receiver $2\sigma^2E/N_0=130$,[33] and we require $P_e\leq 0.01$. From the $\gamma=0$ curves of Fig. 5 and Fig. 6 we have then the requirement $|\lambda|\leq 0.5$. Choosing $|\lambda|=0.5$, we have from Fig. 8: $\Delta f_g=W_g$ and

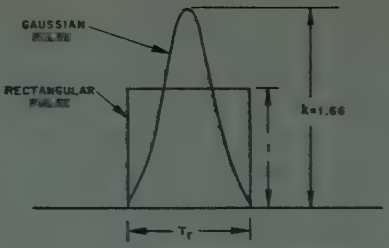


Fig. 10—The "equivalent" Gaussian and rectangular pulses of the example in the text.

$$\Delta f_r = \frac{0.6}{T_r} \cong 0.682\ W_r.$$

If we define the over-all bandwidth of each system as the difference between the upper half-power frequency of the upper band and the lower half-power frequency of the lower band, we have the over-all bandwidths

$$\left.\begin{aligned} W_{g_0} &= 2W_g \\ W_{r_0} &= 1.682W_r \end{aligned}\right\}, \tag{50}$$

so, from (48),

$$W_{g_0} \cong 1.75W_{r_0}. \tag{51}$$

That is, under the conditions described above, the penalties attached to using the Gaussian pulse shape of Fig. 10 instead of the rectangular pulse shape are 4.4 db greater peak power and 75 per cent greater over-all half-power bandwidth.

APPENDIX I. THE COMPLEX CORRELATION FUNCTION

Suppose we have two narrow-band complex transient waveforms $\mu(t)=m(t)e^{j2\pi f_0t}$ and $\nu(t)=n(t)e^{j2\pi f_0t}$. Their complex cross-correlation function is defined as

$$\psi(\tau) = \frac{1}{2}\int \mu^*(t)\nu(t-\tau)dt \tag{52}$$

where the integration is over all intervals of nonzero integrand. The real part of $\psi(\tau)$ is

$$\hat{\psi}(\tau) = \frac{1}{2}\int [\hat{\mu}(t)\hat{\nu}(t-\tau) + \tilde{\mu}(t)\tilde{\nu}(t-\tau)]dt \tag{53}$$

in which

$$\hat{\mu}(t) = \hat{m}(t)\cos 2\pi f_0t - \tilde{m}(t)\sin 2\pi f_0t \tag{54a}$$

$$\tilde{\mu}(t) = \hat{m}(t)\sin 2\pi f_0t + \tilde{m}(t)\cos 2\pi f_0t \tag{54b}$$

and similar expressions hold for $\nu(t)$ and $\tilde{\nu}(t)$. From (54a)

$$\hat{\mu}\left(t-\frac{1}{4f_0}\right) = \hat{m}\left(t-\frac{1}{4f_0}\right)\sin 2\pi f_0t + \tilde{m}\left(t-\frac{1}{4f_0}\right)\cos 2\pi f_0t \tag{55}$$

---

[33] This corresponds to an average received signal-to-noise power ratio of about 21 db *per band* for rectangular pulses and about 20 db *per band* for Gaussian pulses. (See footnote 28.)

Now, it has been assumed that $\mu(t)$ represents a narrow-band waveform. This implies that $m(t)$ remains essentially constant over many cycles of carrier, so we may write

$$m\left(t - \frac{1}{4f_0}\right) = m(t),$$

and hence from (55) and 54(b)

$$\hat{\mu}\left(t - \frac{1}{4f_0}\right) = \mu(t). \tag{56}$$

Similarly

$$\hat{\nu}\left(t - \frac{1}{4f_0}\right) = \nu(t). \tag{57}$$

Using (56) and (57) in (53), we notice that the integrals of both terms on the right are equal, so

$$\hat{\psi}(\tau) = \int \hat{\mu}(t)\hat{\nu}(t - \tau)dt. \tag{58}$$

That is, the real part of $\psi(\tau)$ is the cross-correlation function of physical waveforms $\hat{\mu}(t)$ and $\hat{\nu}(t)$.

By inserting expressions for $\hat{\mu}(t)$ and $\hat{\nu}(t)$ in the form of (54a) in (58) one obtains, after some trigonometric manipulations and the use of the narrow-band assumption to eliminate integrals of double-frequency terms,

$$\hat{\psi}(\tau) = A(\tau) \cos 2\pi f_0\tau + B(\tau) \sin 2\pi f_0\tau, \tag{59}$$

where

$$A(\tau) = \frac{1}{2}\int [\hat{m}(t)\hat{n}(t - \tau) + \tilde{m}(t)\tilde{n}(t - \tau)]dt, \tag{60a}$$

$$B(\tau) = \frac{1}{2}\int [\hat{m}(t)\tilde{n}(t - \tau) - \tilde{m}(t)\hat{n}(t - \tau)]dt. \tag{60b}$$

The envelope of $\hat{\psi}(\tau)$ is just

$$\sqrt{A^2(\tau) + B^2(\tau)}.$$

But one can easily show from (52) that

$$|\psi(\tau)| \equiv \sqrt{\hat{\psi}^2(\tau) + \tilde{\psi}^2(\tau)} = \sqrt{A^2(\tau) + B^2(\tau)}$$

so we have

$$|\psi(\tau)| = env\, \hat{\psi}(\tau). \tag{61}$$

That is, the magnitude of the complex cross-correlation function is just the envelope of the physical cross-correlation function.

Appendix II. Cross-Correlation Techniques

Here we review methods of obtaining the terms in (15) by physical operations. In particular, we consider three techniques: multiplication and low-pass filtering,[34–37] multiplication and band-pass filtering,[37] and matched filtering.[38]

A. Multiplication and Low-Pass Filtering

In order to obtain $\mathrm{Re}[r_m(\tau)e^{-j\delta}]$, one multiplies the received signal by the stored replica of the mth transmitted waveform, which has been delayed by such an amount that its modulation is delayed by τ (within a fraction of a carrier period), and its carrier phase is shifted by δ.[39] The multiplier output is fed into a low-pass short-time integrating filter whose output is then (*cf.* Appendix I):

$$\begin{aligned} e_0(t) &= \frac{1}{2}\ \mathrm{Re}\int_{t-T}^{t} \xi^*(t)x_m(t - \tau)e^{j(2\pi f_0 t - \delta)}dt, \\ &= \frac{1}{2}\,\mathrm{Re}\left\{e^{-j\delta}\int_{t-T}^{t} z^*(t)x_m(t - \tau)dt\right\}. \end{aligned} \tag{62}$$

T, the integrating time of the filter, is taken to be equal to the duration of $\xi_m(t)$ [and hence $x_m(t)$]. Thus, we have from (62) and (13),

$$e_0(\tau + T) = \mathrm{Re}\left\{r_m(\tau)e^{-j\delta}\right\}. \tag{63}$$

The required quantity is, therefore, the output of the integrating filter sampled at $t = \tau + T$ (where $t = 0$ corresponds to the start of the transmission interval[39]).

In order to obtain $|r_m(\tau)|^2$, it suffices to obtain $\mathrm{Im}\{r_m(\tau)e^{-j\delta}\}$, square it, and add this to the square of $\mathrm{Re}\{r_m(\tau)e^{-j\delta}\}$ obtained above. To obtain $\mathrm{Im}\{r_m(\tau)e^{-j\delta}\}$ physically, one gives to the delayed replica of $\hat{\xi}_m(t)$, described above, an additional phase shift of 90°. This quadrature waveform is then multiplied by the received waveform, the product passed into a low-pass short-time integrating filter, and the output of the filter sampled at $t = \tau + T$. This sample value is, by direct analogy with the previous derivation,

$$e_0'(\tau + T) = \mathrm{Re}\left\{r_m(\tau)e^{-j(\delta+\pi/4)}\right\} = \mathrm{Im}\left\{r_m(\tau)e^{-j\delta}\right\} \tag{64}$$

which is what we require. The last equality in (64) is readily proven by expressing both sides in terms of the real and imaginary parts of $r_m(\tau)$ and of the exponentials.

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[34] Y. W. Lee, T. P. Cheatham, and J. B. Wiesner, "The Application of Correlation Functions in the Detection of Small Signals in Noise," M.I.T., Cambridge, Mass., Res. Lab. of Electronics, Tech. Rep. 141; October 13, 1949.

[35] R. M. Fano, "Signal-to-Noise Ratio in Correlation Detectors," M.I.T., Cambridge, Mass., Res. Lab. of Electronics, Tech. Rep. 186, February 19, 1951.

[36] W. B. Davenport, Jr., "Correlator Errors Due to Finite Observation Intervals," M.I.T., Cambridge, Mass., Res. Lab. of Electronics, Tech. Rep. 191; March 8, 1951.

[37] P. E. Green, Jr., "The output signal-to-noise ratio of correlation detectors," IRE Trans. on Information Theory, vol. IT-3, pp. 10–18; March, 1957.

[38] R. M. Fano, "Communication in the presence of noise," M.I.T., Cambridge, Mass., unpublished lecture notes; 1951.

[39] It is to be remembered that the (coherent) receiver is assumed to know τ and δ, and to have time and phase bases which are synchronous with those in the transmitter.

B. Multiplication and Band-Pass Filtering

In order to eliminate the additional multiplier and integrator needed to obtain $|r_m(\tau)|^2$ with low-pass filtering, the following method may be used.

The *m*th stored waveform is delayed by such an amount that its modulation is delayed by τ (within a fraction of a carrier period), and its carrier is in phase with that of the undelayed waveform. Before multiplication of the delayed stored waveform and the received waveform, one or the other is shifted in frequency by an amount Δ cps. If the product waveform, whose spectrum is centered at Δ cps, is integrated by a short-time *band-pass* integrator with impulse response

$$k(t) = \begin{cases} \text{Re}\,\{e^{i2\pi\Delta t}\} & 0 \leq t \leq T \\ 0 & \text{elsewhere} \end{cases} \tag{65}$$

the integrator output is

$$e_0(t) = \frac{1}{2}\,\text{Re}\left\{e^{\pm i2\pi\Delta t}\int_{t-T}^{t} z^*(t)x_m(t-\tau)dt\right\}. \tag{66}$$

The sign of the exponent is positive if the received signal is shifted down by Δ or the stored signal shifted up, and negative if the received signal is shifted up or the stored signal down. If we sample $e_0(t)$, which is a band-pass waveform centered on Δ cps, at (modulation) time $t=\tau+T$, in phase $\mp\delta$, we then get the required $\text{Re}\{r_m(\tau)e^{-i\delta}\}$; the phase is of course measured here with respect to that of the shifting oscillator, which goes through zero phase at $t=0$. Note that the envelope of the waveform $e_0(t)$ is just

$$\left|\frac{1}{2}\int_{t-T}^{t} z^*(t)xm(t-\tau)dt\right|,$$

so $|r_m(\tau)|$ is just the envelope of e_0 at $t=\tau+T$.

C. Matched Filtering

If we have a filter with impulse response

$$h_m(t) = \text{Re}\,\xi_m(-t) \tag{67}$$

the response of this filter to the received signal is just

$$e_0(t) = \frac{1}{2}\,\text{Re}\left\{e^{-i2\pi ft}\int z^*(\sigma)x_m(\sigma-t)d\sigma\right\} \tag{68}$$

where the integral is taken over all intervals of nonzero integrand. Thus

$$e_0(t) = \text{Re}\,\{r_m(t)e^{-i2\pi ft}\}, \tag{69}$$

so $\text{Re}\{r_m(\tau)e^{-i\delta}\}$ is $e_0(t)$, sampled at (modulation) time τ, in phase δ. Similarly, $|r_m(\tau)|$ is the envelope of e_0, sampled at $t=\tau$.

The filter of (67) is called the filter which is "matched"[40] to $\text{Re}\,\xi(t)$; its transfer function is the complex conjugate of the signal spectrum. As written in (67) it is unrealizable, since $h_m(t)$ is not zero for $t<0$. However, by inserting a delay T, *i.e.*, by letting $h_m(t)=\text{Re}\,\xi_m(T-t)$, the filter is made realizable; the output samples are now taken exactly T seconds later than indicated above.

Note from (69) that the matched filter output is the *complete* crosscorrelation function of the received signal and the *m*th stored waveform as a function of time; introduction of the parameter τ does not take place until after the matched-filter processing of the received signal. On the other hand, the correlation techniques described by (62) and (66) give the required crosscorrelation function evaluated only for a *particular* value of the parameter τ, which is introduced before the processing of the received signal.

APPENDIX III. PROBABILITY OF ERROR, COHERENT CASE

We may assume, without loss of generality, that $\tau=0$ and $\delta=0$ since in any case these are both known to the receiver. Then, letting

$$D = \left[\frac{\sigma^2}{N_0}\,|r_1(0)|^2 + \alpha\hat{r}_1(0)\right] - \left[\frac{\sigma^2}{N_0}\,|r_2(0)|^2 + \alpha\hat{r}_2(0)\right] \tag{70}$$

we see from (15) that the receiver guesses signal 1 as the transmitted signal if $D>0$ and signal 2 if $D<0$. Because of the symmetry of the system, there will be the same probability of error when signal 1 is sent as when signal 2 is sent. Thus we can compute the over-all probability of error by assuming that signal 1 was sent, and finding the probability that $D<0$.

We first define four new variables:

$$\begin{aligned} w_1 &= \frac{\sigma}{N_0}\,\text{Re}\int z^*(t)x_1(t)dt + \frac{\alpha}{\sigma} \\ w_2 &= \frac{\sigma}{N_0}\,\text{Im}\int z^*(t)x_1(t)dt \\ w_3 &= \frac{\sigma}{N_0}\,\text{Re}\int z^*(t)x_2(t)dt + \frac{\alpha}{\sigma} \\ w_4 &= \frac{\sigma}{N_0}\,\text{Im}\int z^*(t)x_2(t)dt. \end{aligned} \tag{71}$$

Then, from (13) and (71), $D<0$ implies

$$w_1^2 + w_2^2 - w_3^2 - w_4^2 < 0. \tag{72}$$

Now, the hypothesized received signal is the sum of a Gaussian noise waveform and the output of the fading medium assuming signal 1 was sent. Thus in terms of modulation waveforms [*cf.* (7)],

---

[40] J. H. Van Vleck and D. Middleton, "A theoretical comparison of the visual, aural, and meter reception of pulsed signals in the presence of noise," *J. Appl. Phys.*, vol. 17, pp. 940–971; November, 1946.

$$z(t) = ax_1(t)e^{-j\theta} + n(t), \tag{73}$$

where $n(t)$ is the modulation waveform of the noise. a and θ share the joint distribution of (10); using this it is easy to show that the real and imaginary parts of the first term in (73) are Gaussianly distributed.[8] The real and imaginary parts of $n(t)$ are also Gaussianly distributed.[3] Hence the two parts of $z(t)$ are Gaussianly distributed. It then follows that the real and imaginary parts of $\int z^*(t)x_i(t)dt$ $(i=1, 2)$, and hence w_1, w_2, w_3, and w_4, share joint Gaussian distributions.[41] Thus $R=w_1^2+w_2^2-w_3^2-w_4^2$ is a quadratic form of correlated Gaussian variables.

It is easily shown that the characteristic function of a quadratic form, R, of Gaussian variables is given by[42]

$$F_R(ju) = \overline{e^{juR}} = \frac{\exp\left[-\frac{1}{2}\overline{W}_t M^{-1}\{I-(I-2juMQ)^{-1}\}\overline{W}\right]}{\left|I - 2juMQ\right|^{1/2}} \tag{74}$$

where I is the unit matrix, Q is the matrix of the quadratic form, M is the moment matrix of the variables,[43] $\overline{W}$ is the (column) matrix of the means of the variables,[44] "t" denotes "transpose of," and $|\cdots|$ denotes "determinant of." The probability density distribution of R is the Fourier transform of F_R:

$$pr[R] = \frac{1}{2\pi j}\int_{-j\infty}^{j\infty} F_R(s)e^{-sR}ds. \tag{75}$$

Hence, the probability of error is

$$\begin{aligned} P_e = Pr[R<0] &= \int_{-\infty}^{0} pr[R]dR \\ &= -\frac{1}{2\pi j}\int_{-j\infty}^{j\infty} \frac{F_R(s)}{s}\, ds. \end{aligned} \tag{76}$$

The path of integration of the last integral in (76) is taken to be indented to the left at all j-axis singularities.

In order to evaluate (76), we must know $F_R(s)$, and this entails finding the matrices of means and second moments of the w variables, (71). Using (73), and then (4) and (5), we have

$$\begin{aligned} \int z^*(t)x_1(t)dt &= 2aEe^{j\theta} + \int n^*(t)x_1(t)dt, \\ \int z^*(t)x_2(t)dt &= 2aE\lambda e^{j\theta} + \int n^*(t)x_2(t)dt. \end{aligned} \tag{77}$$

Once we have found the matrices of means and second moments of the real and imaginary parts of the random variables in (77), we can easily obtain these matrices for the w variables of (71). Let

$$\begin{aligned} p &= 2aEe^{j\theta}, \\ q_i &= \int n^*(t)x_i(t)dt \qquad i = 1, 2. \end{aligned} \tag{78}$$

Then

$$\begin{aligned} \mathrm{Re}\int z^*(t)x_1(t)dt &= \hat{p} + \hat{q}_1, \\ \mathrm{Im}\int z^*(t)x_1(t)dt &= \tilde{p} + \tilde{q}_1, \\ \mathrm{Re}\int z^*(t)x_2(t)dt &= \hat{p}\hat{\lambda} - \tilde{p}\tilde{\lambda} + \hat{q}_2, \\ \mathrm{Im}\int z^*(t)x_2(t)dt &= \hat{p}\tilde{\lambda} + \tilde{p}\hat{\lambda} + \tilde{q}_2. \end{aligned} \tag{79}$$

Since we have assumed that a and θ share the joint distribution of (10) with $\delta=0$ we get easily[45]

$$\begin{aligned} \overline{\hat{p}} &= 2\alpha E, \\ \overline{\tilde{p}} &= 0, \\ \overline{\hat{p}^2} &= 4(\alpha^2+\sigma^2)E^2, \\ \overline{\tilde{p}^2} &= 4\sigma^2E^2, \\ \overline{\hat{p}\tilde{p}} &= 0. \end{aligned} \tag{80}$$

From (78) we have

$$\begin{aligned} \hat{q}_i &= \int [\hat{n}(t)\hat{x}_i(t) + \tilde{n}(t)\tilde{x}_i(t)]dt \\ \tilde{q}_i &= \int [\hat{n}(t)\tilde{x}_i(t) - \tilde{n}(t)\hat{x}_i(t)]dt \end{aligned} \qquad i = 1, 2. \tag{81}$$

Noting that $\overline{\hat{n}(t)} = \overline{\tilde{n}(t)} = 0$ (the noise has zero mean), we have

$$\overline{\hat{q}_i} = \overline{\tilde{q}_i} = 0 \qquad i = 1, 2. \tag{82}$$

Since the noise has been assumed white, we have for the two quadrature components:

$$\begin{aligned} \overline{\hat{n}(t)\hat{n}(s)} = \overline{\tilde{n}(t)\tilde{n}(s)} &= N_0\delta(t-s), \\ \overline{\hat{n}(t)\tilde{n}(s)} &= 0, \end{aligned} \tag{83}$$

where N_0 is the noise power density and $\delta(x)$ is the Dirac delta-function. Using (4), (5), (82), and (83), we obtain

$$\begin{aligned} \overline{\hat{q}_1^{\,2}} = \overline{\tilde{q}_1^{\,2}} = \overline{\hat{q}_2^{\,2}} = \overline{\tilde{q}_2^{\,2}} &= 2EN_0, \\ \overline{\hat{q}_1\tilde{q}_1} = \overline{\hat{q}_2\tilde{q}_2} &= 0, \\ \overline{\hat{q}_1\hat{q}_2} = \overline{\tilde{q}_1\tilde{q}_2} &= 2\hat{\lambda}EN_0, \\ \overline{\hat{q}_1\tilde{q}_2} = -\overline{\tilde{q}_1\hat{q}_2} &= 2\tilde{\lambda}EN_0. \end{aligned} \tag{84}$$

Finally, because of the assumed independence of the noise and the multipath medium, we find

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[41] H. Cramér, "Mathematical Methods of Statistics," Princeton University Press, Princeton, N.J., sec. 24.4; 1951.

[42] See footnote 16, Appendix V. For $\overline{W}=0$ this result also appears in P. Whittle, "Hypothesis Testing in Time Series Analysis," Almquist and Wiksells AB, Uppsala, Sweden; 1951.

[43] The elements of M are $m_{ij} = \overline{w_i w_j} - \overline{w_i}\,\overline{w_j}$.

[44] The elements of $\overline{W}$ are $\overline{w_i}$.

[45] See Fig. 2, in which let $\delta=0$, and multiply all vectors by $2E$.

$$
\begin{aligned}
\overline{\hat{p}\hat{q}_1} &= \overline{\hat{p}}\,\overline{\hat{q}_i} = 0,\\
\overline{\hat{p}\tilde{q}_i} &= \overline{\hat{p}}\,\overline{\tilde{q}_i} = 0,\\
\overline{\tilde{p}\hat{q}_i} &= \overline{\tilde{p}}\,\overline{\hat{q}_i} = 0,\\
\overline{\tilde{p}\tilde{q}_i} &= \overline{\tilde{p}}\,\overline{\tilde{q}_i} = 0.
\end{aligned} \tag{85}
$$

The moments in (80), (82), (84), and (85) suffice for the evaluation of the means and the various second self- and cross-moments of the four variables on the left of (79). Using these latter, it is an easy step to compute the matrices of the means and second moments of the w variables, (71). These are

$$
\overline{\boldsymbol{W}} = \begin{bmatrix} \gamma(\beta+1) \\ 0 \\ \gamma(\beta\hat{\lambda}+1) \\ \gamma\beta\tilde{\lambda} \end{bmatrix} \tag{86}
$$

and

$$
\boldsymbol{M} = \beta \begin{bmatrix}
(\beta+1) & 0 & \hat{\lambda}(\beta+1) & \tilde{\lambda}(\beta+1) \\
0 & (\beta+1) & -\tilde{\lambda}(\beta+1) & \hat{\lambda}(\beta+1) \\
\hat{\lambda}(\beta+1) & -\tilde{\lambda}(\beta+1) & \beta|\lambda|^2+1 & 0 \\
\tilde{\lambda}(\beta+1) & \hat{\lambda}(\beta+1) & 0 & \beta|\lambda|^2+1
\end{bmatrix}. \tag{87}
$$

The matrix of the quadratic form $R = w_1^2 + w_2^2 - w_3^2 - w_4^2$ is

$$
\boldsymbol{Q} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}. \tag{88}
$$

Using (86) through (88) we may evaluate the characteristic function, $F_R(ju)$, of (74). The two matrices, $\boldsymbol{M}$ and $(\boldsymbol{I} - 2ju\boldsymbol{MQ})$, in (74) which must be inverted are both of the form

$$
\begin{bmatrix} a & 0 & b & c \\ 0 & a & -c & b \\ b & -c & d & 0 \\ c & b & 0 & d \end{bmatrix}, \tag{89}
$$

which has the inverse

$$
\frac{1}{ad - b^2 - c^2} \begin{bmatrix} d & 0 & -b & -c \\ 0 & d & c & -b \\ -b & c & a & 0 \\ -c & -b & 0 & a \end{bmatrix}. \tag{90}
$$

The determinant of the matrix of (89) is $(ad - b^2 - c^2)^2$. After some matrix manipulations, we obtain, replacing ju by s,

$$
F_R(s) = \frac{\exp\left[\dfrac{k_1 s(1 + k_2 s)}{1 - k_3 s(1 + k_2 s)}\right]}{1 - k_3 s(1 + k_2 s)} \tag{91}
$$

where

$$
\begin{aligned}
k_1 &= \beta\gamma^2[\beta(1 - |\lambda|^2) + 2(1 - \hat{\lambda})],\\
k_2 &= 2(\beta + 1),\\
k_3 &= 2\beta^2(1 - |\lambda|^2).
\end{aligned} \tag{92}
$$

On placing (91) in (76), we note that the resulting integrand has singularities at the origin and at

$$
\frac{1}{2k_2}\left(-1 \pm \sqrt{1 + \frac{4k_2}{k_3}}\right).
$$

The path of integration is along the j axis, indented to the left at the origin. We may simplify the integral in the following way. First we move the path of integration to the left by $1/2k_2$; no singularities are crossed by the path in this process, so the value of the integral remains the same. The new limits of integration are

$$
\left(-j\infty - \frac{1}{2k_2},\ +j\infty - \frac{1}{2k_2}\right).
$$

Next we make the change of variable $s = (1/2k_2)(jz - 1)$; the limits on the z integral are then $(-\infty, +\infty)$. On separating the new integrand in the z variable into its real and imaginary parts, we note that the real part is even and the imaginary part odd about $z = 0$. The integral of the imaginary part thus disappears, and the integral of the real part can be evaluated by doubling its integral over $(0, \infty)$. After a little algebra, we obtain

$$
P_e = \frac{k_4^2 - 1}{\pi} \int_0^\infty \frac{\exp\left[-\dfrac{k_5(z^2 + 1)}{z^2 + k_4^2}\right]}{(z^2 + 1)(z^2 + k_4^2)}\, dz, \tag{93}
$$

where

$$
\begin{aligned}
k_4 &= \sqrt{1 + \frac{4k_2}{k_3}}\\
k_5 &= \frac{k_1}{k_3}\cdot
\end{aligned} \tag{94}
$$

We next change the integral into trigonometric form by letting

$$
z^2 = k_4^2 \frac{1 - \cos\phi}{1 + \cos\phi}\cdot
$$

Using this in (93) and noting that z can be expressed as

$$
z = k_4 \tan\frac{\phi}{2} = k_4 \frac{\sin\phi}{1 + \cos\phi},
$$

we obtain

$$
P_e = \frac{A}{\pi} \int_0^\pi f(\phi) e^{B\cos\phi} d\phi, \tag{95}
$$

vhere

$$A = \frac{k_4^2 - 1}{2k_4} \exp\left[-\frac{k_5(1 + k_4^2)}{2k_4^2} \right],$$

$$B = \frac{k_5}{2k_4^2} (k_4^2 - 1) \tag{96}$$

nd

$$f(\phi) = \frac{1 + \cos\phi}{(k_4^2 + 1) - (k_4^2 - 1)\cos\phi}. \tag{97}$$

The integral in (95) may be evaluated by first exanding $f(\phi)$ in a Fourier cosine series:[46]

$$f(\phi) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos n\phi, \tag{98}$$

vhere

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(\phi) \cos n\phi d\phi. \tag{99}$$

hen, noting that

$$\frac{1}{\pi} \int_0^{\pi} e^{B \cos\phi} \cos n\phi d\phi = I_n(B), \tag{100}$$

vhere I_n is the nth-order modified Bessel function of the rst kind, we have from (95) and (98)

$$P_e = A\left[\frac{a_0}{2} I_0(B) + \sum_{n=1}^{\infty} a_n I_n(B) \right]. \tag{101}$$

From (97) and (99) we can evaluate the a_n's; they urn out to be:[47]

$$a_n = \begin{cases} \dfrac{2}{k_4 + 1} & n = 0 \\[2ex] \dfrac{2k_4}{k_4^2 - 1}\left(\dfrac{k_4 - 1}{k_4 + 1}\right)^n & n > 0. \end{cases} \tag{102}$$

In order to put (101) into the form of (16) we use the ollowing identity:[48]

$$\sum_{n=0}^{\infty} \left(\frac{x}{y}\right)^n I_n(xy) = e^{(x^2+y^2)/2} Q(x, y), \tag{103}$$

vhere $Q(x, y)$ is given by (17). Putting (102) and (103) nto (101), we get

$$ {}_e = A\left[-\frac{1}{k_4 - 1} I_0(B) + \frac{1}{A} Q\left(\frac{k_4 - 1}{k_4} \sqrt{\frac{k_5}{2}}, \frac{k_4 + 1}{k_4} \sqrt{\frac{k_5}{2}} \right) \right]. \tag{104}$$

f we let

$$a = \frac{k_4 - 1}{k_4},$$

$$b = \frac{k_4 + 1}{k_4},$$

$$c = \sqrt{\frac{k_5}{2}}, \tag{105}$$

(104) reduces immediately to (16). The expressions for a, b, and c in (105) may easily be shown to be identical with those in (20), (21), and (22), respectively, through the use of (92) and (94).

APPENDIX IV. PROBABILITY OF ERROR, NONCOHERENT CASE

We may start our derivation of P_e for the noncoherent case at a fairly advanced point by making use of a result of Helstrom.[24] The result gives P_e for the noncoherent case for a fixed path [*cf.* (37)]. Now since in the noncoherent case the form of the ideal receiver for a fading path is the same as that for a fixed path[49]—comparison of the two correlation envelopes at a sampling instant—Helstrom's result may alternatively be considered as the conditional probability of error for a *fading path* for a given path strength. If we then average this conditional probability of error over all path strengths using the path strength distribution of (11), the result will be P_e for the noncoherent fading case.

Our starting point is Helstrom's (54). This is, in our terminology,

$$P_e(a) = \frac{\sqrt{1 - |\lambda|^2}}{4\pi} \cdot e^{-\beta a^2/4\sigma^2} \int_0^{2\pi} \frac{\exp\left[\dfrac{\beta a^2 |\lambda| \cos\phi}{4\sigma^2}\right]}{1 - |\lambda| \cos\phi} d\phi. \tag{106}$$

$P_e(a)$ is the probability of error on condition that path strength is a. The over-all probability of error is then

$$P_e = \int_0^{\infty} pr[a] P_e(a) da \tag{107}$$

where $pr[a]$ is given by (11).

On placing (106) and (11) in (107), and integrating first on a,[50] we arrive, after some algebraic manipulation, at

$$P_e = \frac{\sqrt{1 - |\lambda|^2}}{4\pi} \cdot e^{-\gamma^2/2} \int_0^{2\pi} \left[\frac{1}{1 - |\lambda| \cos\phi} - \frac{\mu}{1 - \mu|\lambda| \cos\phi} \right] \cdot \exp\left[\frac{\mu\gamma^2}{\beta(1 - \mu|\lambda| \cos\phi)} \right] d\phi, \tag{108}$$

where μ, β, and γ are given by (18) and (19).

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[46] I am indebted to Dr. W. L. Doyle for this suggestion.

[47] W. Gröbner and N. Hofreiter, "Integraltafel," Springer-Verlag, ienna, pt. II, p. 112; 1950. See eq. 24.

[48] J. I. Marcum, "A Statistical Theory of Target Detection by ulsed Radar," "Mathematical Appendix," Rand Corp., Santa onica, Calif., Rep. RM-753, p. 5; July 1, 1948.

[49] Note from (15) that this is not true in the coherent case.

[50] Magnus and Oberhettinger, *op. cit.*, p. 35.

In order to evaluate (108), we must evaluate integrals of the form

$$y(A, B, C) = \int_0^{2\pi} \frac{\exp\left[\dfrac{A}{1 - B\cos\phi}\right]}{1 - C\cos\phi}\, d\phi, \qquad (109)$$

where $0 \leq B \leq C \leq 1$. This may be done as follows.[51] The derivative of y with respect to A is

$$\frac{\partial y(A, B, C)}{\partial A} = \int_0^{2\pi} \frac{\exp\left[\dfrac{A}{1 - B\cos\phi}\right]}{(1 - B\cos\phi)(1 - C\cos\phi)}\, d\phi. \qquad (110)$$

Noting that

$$\frac{1}{(1 - B\cos\phi)(1 - C\cos\phi)} = -\frac{\dfrac{B}{C - B}}{1 - B\cos\phi} + \frac{\dfrac{C}{C - B}}{1 - C\cos\phi}, \qquad (111)$$

we may write (110) as

$$\frac{\partial y(A, B, C)}{\partial A} = \frac{C}{C - B}\, y(A, B, C) - \frac{B}{C - B}\, y(A, B, B). \qquad (112)$$

The integral

$$y(A, B, B) = \int_0^{2\pi} \frac{\exp\left[\dfrac{A}{1 - B\cos\phi}\right]}{1 - B\cos\phi}\, d\phi, \qquad (113)$$

may be put in a recognizable form by making the change of variable

$$t = \frac{1 - B^2}{B(1 - B\cos\phi)} - \frac{1}{B}. \qquad (114)$$

Doing this, we obtain[52]

$$y(A, B, B) = \frac{2\pi}{\sqrt{1 - B^2}}\, I_0\left(\frac{BA}{1 - B^2}\right) \exp\left[\frac{A}{1 - B^2}\right]. \qquad (115)$$

Now (112) is a differential equation in $y(A, B, C)$ which may be solved in terms of $y(A, B, B)$:

$$y(A, B, C) = \exp\left[\frac{CA}{C - B}\right]\left[\frac{2\pi}{\sqrt{1 - C^2}} - \frac{B}{C - B}\int_0^A y(x, B, B)\exp\left[-\frac{Cx}{C - B}\right] dx\right]. \qquad (116)$$

The evaluation of $y(A, B, C)$ is thus reduced to the evaluation of

$$Z = \int_0^A e^{-K_1 x} I_0(K_2 x)\, dx, \qquad (117)$$

where

$$K_1 = \frac{C}{C - B} - \frac{1}{1 - B^2} = \frac{B(1 - BC)}{(C - B)(1 - B^2)}$$

$$K_2 = \frac{1}{1 - B^2}. \qquad (118)$$

On using in (117) the integral representation of $I_0(K_2 x)$ afforded by (100), and integrating on x first, one obtains

$$Z = g(0) - g(A)e^{-K_1 A}, \qquad (119)$$

where

$$g(A) = \frac{1}{\pi}\int_0^{\pi} \frac{e^{K_2 A}\cos\phi}{K_1 - K_2\cos\phi}\, d\phi. \qquad (120)$$

From (118) and the fact that $0 \leq B \leq C \leq 1$, it is easily shown that $K_1 \geq K_2$.

On placing the Fourier series expansion

$$\frac{1}{K_1 - K_2\cos\phi} = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos n\theta \qquad (121)$$

where[47]

$$a_n = \frac{2}{\sqrt{K_1^2 - K_2^2}}\left[\frac{K_1}{K_2}\left(1 - \sqrt{1 - \left(\frac{K_2}{K_1}\right)^2}\right)\right]^n \qquad (122)$$

in (120), one obtains, using (100),

$$g(A) = \frac{a_0}{2} I_0(K_2 A) + \sum_{n=1}^{\infty} a_n I_n(K_2 A). \qquad (123)$$

Then, on using (103), (123) becomes

$$g(A) = \frac{1}{\sqrt{K_1^2 - K_2^2}} \cdot \left[2e^{K_1 A} Q\left(\sqrt{K_1 A\left(1 - \sqrt{1 - \left(\frac{K_2}{K_1}\right)^2}\right)}, \sqrt{K_1 A\left(1 + \sqrt{1 - \left(\frac{K_2}{K_1}\right)^2}\right)}\right) - I_0(K_2 A)\right]. \qquad (124)$$

Note that

$$g(0) = \frac{1}{\sqrt{K_1^2 - K_2^2}} = \frac{C - B}{B}\sqrt{\frac{1 - B^2}{1 - C^2}}. \qquad (125)$$

Using (124) and (125) in (119), and the result in (116), we obtain for the desired integral

[51] I am indebted to Dr. M. A. Steinberg for the following derivation, culminating in (116).

[52] Bateman Manuscript Project, "Higher Transcendental Functions," McGraw-Hill Book Co., Inc., New York, N. Y., vol. II, p. 81; 1953. See eq. (10).

$$y(A, B, C) = \frac{2\pi \exp\left[\frac{CA}{C-B}\right]}{\sqrt{1-C^2}}$$

$$\cdot\left[2Q\left(\sqrt{K_1A\left(1-\sqrt{1-\left(\frac{K_2}{K_1}\right)^2}\right)},\ \sqrt{K_1A\left(1+\sqrt{1-\left(\frac{K_2}{K_1}\right)^2}\right)}\right) - I_0(K_2A)e^{-K_1A}\right], \tag{126}$$

where $K_1(B, C)$ and $K_2(B, C)$ are given by (118). It can be shown that (126) indeed reduces to (115) in the limit $B=C$.

From (108), we have

$$P_e = \frac{\sqrt{1-|\lambda|^2}}{4\pi} e^{-\gamma^2/2}\left[y\left(\frac{\mu\gamma^2}{\beta}, \mu|\lambda|, |\lambda|\right) - \mu y\left(\frac{\mu\gamma^2}{\beta}, \mu|\lambda|, \mu|\lambda|\right)\right]. \tag{127}$$

Eq. (16), with a, b, and c as defined in (34), (35) and (36), follows directly on substitution of (115) and (126) into (127).

Acknowledgment

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Diffraction by Smooth Cylindrical Mountains*

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Summary—**This paper is a contribution to the problem of diffraction of EM waves by the smooth crest of a perfectly reflecting mountain. Model experiments at *K*-band frequencies with mountains of various radii of curvature have been made. The results are compared to an improved Fresnel theory where the reflections of the waves at the surface of the cylinder near its crest are taken into consideration and a correction factor from Fock's theory of grazing incidence is used. The results are also compared to Artmann's and Rice's theories.**

I. Introduction

A SITUATION sometimes encountered when electromagnetic waves propagate over the surface of the earth is that a mountain range separates a receiving station from the transmitter, causing a diffracted field which may be stronger than one without the mountain. This effect is known as obstacle gain.

In the usual theoretical treatment the mountain has been replaced by a vertical half-plane, and the predictions of this knife edge theory have been found to agree reasonably well with experimental results obtained in different mountainous areas.[1,2] However, agreement has not been good enough in several other experiments to consider them a justification of the theory. Reference is made to a paper by Crysdale, *et al.*[3] One reason for such discrepancies may be that the knife edge approximation is not adequate and should be replaced by a theory for mountains with a smooth cylindrical crest. Rice[4] has derived a theory for a parabolic cylinder, but it has the disadvantage that its numerical evaluation is difficult in many cases, for instance in the one encountered by Crysdale.

It is obvious that this problem is closely related to the scattering of electromagnetic waves by circular

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[1] F. H. Dickson, J. J. Egli, J. W. Herbstreit, and G. S. Wickizer, "Large reductions of vhf transmission loss and fading by the presence of a mountain obstacle in beyond-line-of-sight paths," PROC. IRE, vol. 41, pp. 967–969; August, 1953.

[2] R. S. Kirby, H. T. Doughterty, and P. L. McQuate, "Obstacle gain measurements over Pikes Peak at 60 to 1046 mc," PROC. IRE, vol. 43, pp. 1467–1472; October, 1955.

[3] J. Crysdale, J. W. B. Day, W. S. Cook, M. E. Psutka, and P. E. Robillard, "An experimental investigation of the diffraction of electromagnetic waves by a dominating ridge," IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-5, pp. 203–210; April, 1957.

[4] S. O. Rice, "Diffraction of plane radio waves by a parabolic cylinder," *Bell Sys. Tech. J.*, vol. 33, pp. 417–504; March, 1954.

cylinders. For good surveys of the existing literature, reference is made to papers by Wait[5] and Adey.[6] For large $ka = 2\pi a/\lambda$ the mathematical difficulties of evaluating existing theoretical solutions are still great (a = radius, λ = free space wavelength).

One of the best theoretical approaches has been made by Fock.[7] His very general theory and its recent extensions by Logan[8] require a considerable amount of mathematical manipulations which, in many cases, is prohibitive. Due to these difficulties, a new approach to the problem was made by model experiments in the laboratory and by the derivation of an improved Fresnel theory. Both approaches lead to some interesting results which are in satisfactory mutual agreement.

II. Theory

A. *Knife Edge Diffraction*

The scalar theory of knife edge diffraction, or diffraction by a conducting half-plane, is based on (1).[9]

$$E = (jk/2\pi)\int_{y=0}^{+\infty}\int_{z=-\infty}^{+\infty}(1/R_1R_2) \cdot \exp\left[-jk(R_1 + R_2)\right] \cos\theta dz dy. \qquad (1)$$

E is the field at receiver T_2 (see Fig. 1) when a spherical wave $(1/R_1)\exp\left[-jk(R_1 - ct)\right]$ is transmitted from T_1. The time dependent factor e^{jkct} is omitted in (1). The present treatment differs slightly from the usual one in that the integration is carried out over the half plane AC which is not in general the continuation of the plane AB of the obstacle. The plane $B'AC$ goes through the edge A of the obstacle and divides angle T_1AT_2 into equal parts. This "symmetrical" method of evaluating (1) simplifies the formulas when the more general case of a mountain with a smooth cylindrical crest will be treated.

The meaning of most of the symbols and notations is obvious from Fig. 1. It may be added that y, z is a rectangular coordinate system in the plane AC, edge A being the z axis. The origin and the points T_1, T_2 lie in one plane perpendicular to edge A. Since the theory will be confined to small scattering angles, Ψ_1 and Ψ_2, the angle $2\psi_0 = \Psi_1 + \Psi_2$ is also small, and the distances of the stations from the mountain are nearly the same whether they are referred to the plane AB or to the plane of integration $B'AC$ ($d_1 \approx D_1$, $d_2 \approx D_2$).

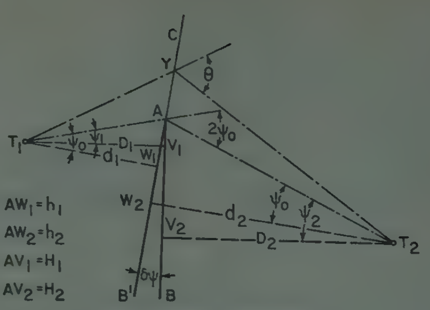

Fig. 1—Knife edge theory.

Another consequence of the assumption of small scattering angles is that the directional beam patterns of the transmitter and receiver could be neglected in (1).

The integration with respect to z is carried out in the usual manner leading to

$$E = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\int_0^{\infty} e^{-jk[R_1+R_2]}\cos\theta dy \qquad (2)$$

where

$$2/d = 1/d_1 + 1/d_2. \qquad (3)$$

For a knife edge mountain the integration with respect to y can also be carried out. The result is denoted by $E_k(2\psi_0)$ to indicate that it is the field produced by a knife edge when the scattering angle is $2\psi_0$.

It is

$$E_k(2\psi_0) = E_k(0)\left[1 - (C + S) + j(S - C)\right] \cdot \exp\left[-jk\psi_0^2(d_1 + d_2 - 2d)/2\right] \qquad (4)$$

where

$$E_k(0) = \frac{\exp\left[-jk(d_1 + d_2)\right]}{2(d_1 + d_2)} \qquad (5)$$

$$C = C\left(\psi_0\sqrt{\frac{2kd}{\pi}}\right), \qquad S = S\left(\psi_0\sqrt{\frac{2kd}{\pi}}\right)$$

are the well-known Fresnel integrals.

B. *Diffraction by Cylindrical Mountain*

The case of diffraction by a mountain with a smooth crest is illustrated by Fig. 2. It is assumed that the mountain (which is drawn like a wall of thickness $2a$ with parallel sides) is topped by a half cylinder of radius a with its axis through point M. The tangents to the cylinder through T_1 and T_2 intersect at N; $MANC$ is the plane of reference and of integration in the same sense as in the knife edge case. The scattering angle, $2\psi_0 = \Psi_1 + \Psi_2$ is assumed small and $d_1 \approx D_1$, $d_2 \approx D_2$.

The effects taking place in the case of Fig. 2 are the following:

1) Radiation travels from T_1 to Y where it acts as a source of a secondary wavelet which irradiates T_2. This scattered radiation is exactly the same as in the case of a knife edge mountain.

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[5] J. R. Wait, "Scattering of a plane wave from a circular dielectric cylinder at oblique incidence," *Can. J. Physics*, vol. 33, pp. 189–195; May, 1955.

[6] A. W. Adey, "Diffraction of microwaves by long metal cylinders," *Can. J. Phys.*, vol. 33, pp. 407–419; August, 1955.

[7] V. Fock, "The distribution of currents induced by a plane wave on the surface of a conductor," *J. Phys.* (*USSR*), vol. 10, pp. 130–136; February, 1946.

"The field of a plane wave near the surface of a conducting body," *J. Phys.* (*USSR*), vol. 10, pp. 399–409; May, 1946.

[8] The authors are indebted to N. Logan for making available to them extensive tables of the Fock functions for positive values of the independent variable and for discussions of his improved derivations of more general formulas before publication.

[9] See, *e.g.*, M. Born, "Optik," Julius Springer, Berlin, Ger., p. 153; 1933.

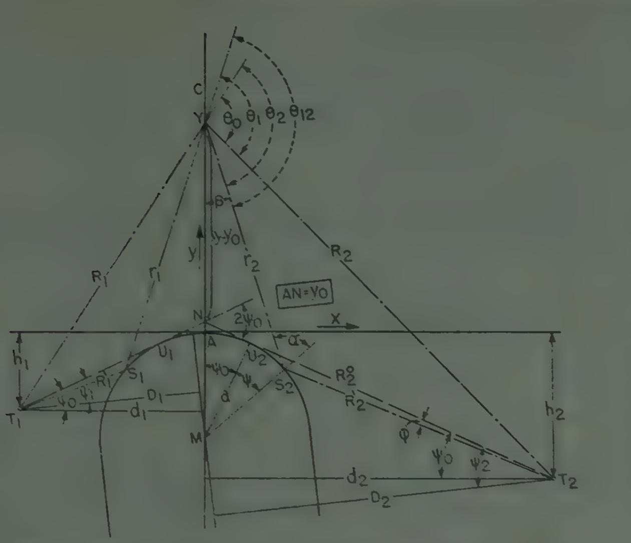

Fig. 2—Four ray theory for mountain with smooth crest.

2) Radiation travels from T_1 to S_1 and is reflected towards point Y where it causes another secondary wavelet which also irradiates T_2.
3) The radiation from both secondary wavelets mentioned in 1 and 2 is reflected at S_2 to reach T_2 via path YS_2T_2.

Hence, there are four different paths along which radiation can travel from T_1 to T_2, *viz.*, T_1YT_2, $T_1S_1YT_2$, $T_1YS_2T_2$, and $T_1S_1YS_2T_2$. The total scattering field at T_2 can be obtained when the integral in (2) is replaced by the four integrals of (6).

$$
\begin{aligned}
E = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\bigg\{\int_{y_0}^{\infty} &\exp\left[-jk(R_1+R_2)\right]\cos\theta_0 dy\\
&+\rho\int_{y_0}^{\infty}\mathrm{Div}\,(S_1)\exp\left[-jk(R_1'+r_1+R_2)\right]\cos\theta_1 dy\\
&+\rho\int_{y_0}^{\infty}\mathrm{Div}\,(S_2)\exp\left[-jk(R_1+r_2+R_2')\right]\cos\theta_2 dy\\
&+\rho^2\int_{y_0}^{\infty}\mathrm{Div}\,(S_1)\,\mathrm{Div}\,(S_2)\\
&\cdot\exp\left[-jk(R_1'+r_1+r_2+R_2')\right]\cos\theta_{12}dy\bigg\}. \qquad (6)
\end{aligned}
$$

This equation requires two explanations.

1) The factor ρ indicates change of phase and/or intensity on reflection. In Section II-C it will be shown that, for a perfect conductor, $\rho=+0.7$ for vertical polarization (electric vector perpendicular to cylinder axis) and $\rho=-1.0$ for horizontal polarization (electric vector parallel to cylinder axis.)
2) The intensity of a beam which is reflected by a curved surface is reduced due to its energy being spread over a wider angle. The divergence factors $\mathrm{Div}(S_1)$ and $\mathrm{Div}(S_2)$ representing these intensity losses for reflections at S_1 or S_2 are given by

$$
\mathrm{Div}\,(S_i) = 1\Bigg/\sqrt{1+\frac{2\sec\alpha_i}{a(1/R_i'+1/r_i)}}\quad (i=1,2) \qquad (7)
$$

where α_1 and α_2 are the angles of incidence. Eq. (7) is easily obtained from (22) of a paper by Riblet and Barker.[10]

The first integral of (6) is evaluated as in the knife edge case; the only difference is that y_0 (distance between A and N) should be added to h_1 and h_2. However, $y_0 \ll h_1$, h_2 for small scattering angles $2\psi_0$ and large distances d_1, d_2 so that, with these restrictions, the first term is the same as in the knife edge case. The evaluation of the third integral of (6) may be discussed as an example. The second integral can be treated in exactly the same, and the fourth integral in a very similar manner.

The evaluation depends on the behavior of the exponent $R_1+r_2+R_2'$ and of the factors $\mathrm{Div}(S_2)$ and $\cos\theta_2$ for increasing y. It is seen from Fig. 2 that point S_2 does not move much when point Y goes to infinity. Hence, R_2' remains almost constant while r_2 increases approximately as fast as y. R_1 increases at the same rate as in the knife edge case $(y+h_1)^2/d_1$. It can therefore be expected that large values of y do not contribute much to the value of the integral because the exponent oscillates too rapidly. In addition it is seen that the angle θ_2 grows rapidly when Y moves away from N so that $\cos\theta_2 \to 0$. Also the divergence factor $\mathrm{Div}(S_2)$ becomes small for large y as $\sec\alpha_2 \approx \sqrt{2}$, $a/R_2' \ll 1$ and $a/r_2 \to 0$.

These considerations make it appear likely that the main contribution to the integral comes from points Y near N. To justify this assumption and to calculate the integral it is convenient to express all the variables as functions of the angle ψ between the two radii MU_2 and MS_2.

$$
\begin{aligned}
y = a[\sin(\psi+\psi_0)\tan(2\psi+\phi+\psi_0)&\\
+\cos(\psi+\psi_0)-1]&\qquad (8a)
\end{aligned}
$$

$$
R_1 = d_1 + (y+h_1)^2/2d_1 \qquad (8b)
$$

$$
r_2 = a\sin(\psi+\psi_0)/\cos(2\psi+\phi+\psi_0) \qquad (8c)
$$

$$
R_2' = \sqrt{4a^2\sin^4\frac{\psi}{2}+(R_2^0-a\sin\psi)^2} \qquad (8d)
$$

ϕ follows from $R_2^0\sin\phi = 2a\sin\dfrac{\psi}{2}\sin(\phi+\psi/2)$ (8e)

$$
\theta_2 = 2\psi+\psi_0+\phi+\tan^{-1}[(y+h_1)/d_1] \qquad (8f)
$$

$$
\mathrm{Div}\,(S_2) = 1\Bigg/\sqrt{1+\frac{2r_2d_2}{a(r_2+d_2)\sin(\psi+\phi)}}. \qquad (8g)
$$

It may be recalled that ψ_0 has been assumed to be small. Hence, in the following series expansions obtained from (8) ψ and ψ_0 are treated as small angles.

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[10] H. J. Riblet and C. B. Baker, "A general divergence formula," *J. Appl. Phys.*, vol. 19, pp. 63–70; January, 1948.

$$y = 2a\psi_0\psi + (3a + a^2\psi_0/d_2)\psi^2/2 + \psi^3 a^2/(2d_2) \quad (9a)$$

$$R_1 = d_1(1 + \psi_0^2/2) + 2a\psi_0^2\psi + 3a\psi_0\psi^2/2 + [3/d_1 + 1/(2d_2)]a^2\psi_0\psi^3 \quad (9b)$$

$$r_2 = a\psi_0 + a\psi(1 + 2\psi_0^2) + 7a\psi_0\psi^2/2 + [11/6 + 3a\psi_0/(2d_2)]a\psi^3 \quad (9c)$$

$$R_2' = d_2(1 + \psi_0^2/2) - a\psi_0 - a\psi + a\psi^3/6 \quad (9d)$$

$$\phi = a\psi^2/(2d_2) + a^2\psi^3/(2d_2^2) \quad (9e)$$

$$\cos\theta_2 = 1 \quad (9f)$$

$$\text{Div}\,(S_2) = \sqrt{\psi/(3\psi + 2\psi_0)} \quad (9g)$$

and

$$R_1 + r_2 + R_2' = (d_1 + d_2)(1 + \psi_0^2/2) + 4a\psi_0^2\psi + [5 + \psi_0\{a/d_2 + 11a/(4d_1)\}]a\psi_0\psi^2 + [2 + a\psi_0\{2/d_2 + 3/d_1\}]a\psi^3 + \cdots \quad (10)$$

From (10) and (9a) one can see that, for $\psi_0=0$ and small y, the exponent $R_1+r_2+R_2'$ behaves as $y^{2/3}$ (or ψ^3) although it has been shown to grow at least as fast as y for larger values of y. Hence, the main contribution to the integral comes from small ψ. If $\psi_0 \neq 0$, terms of lower order in ψ appear at the right side of (10). Since the linear term contains the factor ψ_0^2, small values of ψ are still decisive for the integration providing that ψ_0 is small enough. The linear term in ψ will be omitted in the sequel.

C. Fock Correction

In the preceding part it has been established that only points Y near the surface of the mountain contribute essentially to the integral. This fact makes the approximate calculation of the integral possible. Another consequence is that the factor ρ can be specified. The derivation of (6) has been based on Huygen's principle and on the application of *geometric optics* to the rays coming from the transmitter or from secondary sources. According to geometric optics the total field near the surface is twice the incident field for vertical polarization, and no phase change takes place. It is zero for horizontal polarization, and the phase change is π.

According to the theory of Fock[7] which has been experimentally confirmed by Wetzel and Brick[11] the geometric optics field must be multiplied with a slowly varying factor to obtain the real field in the penumbra zone for large ka. No correction is required for horizontal polarization because geometric optics and Fock's theory predict a vanishing field near the surface. For vertical polarization, geometric optics predicts twice the incident field whereas Fock's theory predicts 1.4 times the incident field. Hence, this theory is brought into agreement with Fock's results by putting

$$\rho_\parallel = -1.0; \quad \rho_\perp = +0.7. \quad (11)$$

D. Evaluation of Integrals

Eq. (6) may be written

$$E_{\perp,\parallel} = E_k + \rho_{\perp,\parallel}E_1 + \rho_{\perp,\parallel}E_2 + \rho_{\perp,\parallel}^2 E_{12} \quad (12)$$

where

$$E_k = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\int \exp\,[-jk(R_1 + R_2)]dy \quad (13a)$$

$$E_1 = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\int \text{Div}\,(S_1) \cdot \exp\,[-jk(R_1' + r_1 + R_2)]dy \quad (13b)$$

$$E_2 = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\int \text{Div}\,(S_2) \cdot \exp\,[-jk(R_1 + r_2 + R_2')]dy \quad (13c)$$

$$E_{12} = \frac{e^{j\pi/4}}{2d_1d_2}\sqrt{\frac{kd}{\pi}}\int \text{Div}\,(S_1)\,\text{Div}\,(S_2) \cdot \exp\,[-jk(R_1' + r_1 + r_2 + R_2')]dy. \quad (13d)$$

On substitution from (9) and (10) into (13c) and by some elementary manipulations (14) is obtained.

$$E_2 = E_k(0)\,\frac{2ka}{\sqrt{\pi kd}}\,e^{j[\pi/4 - \psi_0\,(d_1+d_2)/2]}\int_0^\infty L_2 \cdot \exp\,[-jka(G\psi^2 + F_2\psi^3)]d\psi \quad (14)$$

with

$$L_2 = \sqrt{\psi/(3\psi + 2\psi_0)}\,[2\psi_0 + (3 + a\psi_0/d_2)\psi] \quad (15)$$

$$G = 5\psi_0, \quad F_2 = 2 + a\psi_0(2/d_2 + 3/d_1). \quad (16)$$

The corresponding expression for E_1 is obtained by replacing subscript 2 by subscript 1. In most cases L_1 differs so little from L_2 and F_1 from F_2 that $E_1=E_2$. Usually

$$L_1 = L_2 = \sqrt{\psi(3\psi + 2\psi_0)}$$

$$F_1 = F_2 = 2 + 5a\psi_0/d \quad \text{or even } F_1 = F_2 = 2 \quad (17)$$

are sufficiently accurate approximations. When the corresponding substitutions are made in (13d), a slight complication arises from the fact that the two angles ψ on the side of transmitter T_1 and receiver T_2, which belong to the same point Y, are not equal unless $d_1=d_2$. The two angles may be denoted ψ_1 and ψ_2. The result of the substitution of (9) into (13d) is

$$E_{12} = E_k(0)\,\frac{2k}{\sqrt{\pi kd}}\,e^{j[\pi/4 - \psi_0\,(d_1+d_2)/2]}\int_0^\infty \text{Div}\,(S_1)\,\text{Div}\,(S_2) \cdot \exp\,[-jka\{G'(\psi_1^2 + \psi_2^2) + F_1'\psi_1^3 + F_2'\psi_2^3\}]dy, \quad (18)$$

where

$$G' = 7\psi_0/2, \; F_1' = 2 + 3a\psi_0/(2d_1), \; F_2' = 2 + 3a\psi_0/(2d_2).$$

The angles ψ_1 and ψ_2 are related to y by means of

$$y = 2a\psi_0\psi_1 + (3a + a^2\psi_0/d_1)\psi_1^2/2 = 2a\psi_0\psi_2 + (3a + a^2\psi_0/d_2)\psi_2^2/2. \quad (19)$$

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[11] L. Wetzel and D. B. Brick, "An Experimental Investigation of High-Frequency Current Distributions on Conducting Cylinders," Cruft Lab., Harvard University, Cambridge, Mass., Sci. Rep. No. 4; December 12, 1955.

In most practical cases (18) can be simplified by setting

$$1/d_1 = 1/d + \Delta, \qquad 1/d_2 = 1/d - \Delta$$

and by introducing a new variable ψ by means of

$$y = 2a\psi_0\psi + (3a + a^2\psi_0/d)\psi^2/2. \tag{20}$$

When correction terms of second or higher order are neglected, (18) can be written:

$$E_{12} = E_k(0)\,\frac{2ka}{\sqrt{\pi kd}}\,e^{j[\pi/4-\psi_0^2(d_1+d_2)/2]}\int_0^\infty L \cdot\exp\left[-2jka(G'\psi^2 + F'\psi^3)\right]d\psi \tag{21}$$

where

$$2F' = F_1' + F_2' = 2(2 + 3a\psi_0/[2d])$$

and

$$L = [\psi/(2\psi_0 + 3\psi)][2\psi_0 + 3\psi + a\psi_0\psi/d] \approx \psi. \tag{22}$$

Collecting the results for the four integrals occurring in (12),

$$\begin{aligned} E = E_k(0)e^{-jk\psi_0^2(d_1+d_2)/2}\Big\{&[1 - (1 + j)(C - jS)]e^{jk\psi_0 d} \\ &+ \frac{2ka}{\sqrt{\pi kd}}\,e^{j\pi/4}\Big[\rho\int_0^\infty L_1 \exp\left[-jka(G\psi^2 + F_1\psi^3)\right]d\psi \\ &+ \rho\int_0^\infty L_2 \exp\left[-jka(G\psi^2 + F_2\psi^3)\right]d\psi \\ &+ \rho^2\int_0^\infty \psi \exp\left[-2jka(G'\psi^2 + F'\psi^3)\right]d\psi\Big]\Big\}. \end{aligned} \tag{23}$$

Concerning the numerical evaluation of these integrals it is advantageous to introduce a new variable x which, in the case of the first integral of (23), is defined by

$$x = \beta_1 e^{j\pi/6}\psi \tag{24}$$

with

$$\beta_1 = \sqrt[3]{kaF_1}. \tag{25}$$

In addition

$$x_0 = \beta_1\psi_0. \tag{26}$$

As a result of transformation (24) the path of integration is from zero to $\infty e^{j\pi/6}$ but can be replaced by the real axis from zero to infinity. The justification is the same as for the evaluation of Fresnel's integrals.[12]

The complete expression for E_1 can finally be written

$$E_1 = E_k(0)\,\frac{2\beta_1\rho}{F_1\sqrt{\pi kd}}\cdot e^{-jk\psi_0^2(d_1+d_2)/2} \cdot\int_0^\infty \sqrt{xM}\{\cos P - j\sin P\} \cdot\exp\left[-\left(\frac{5\sqrt{3}x_0}{2F_1}\,x^2 + x^3\right)\right]dx \tag{27}$$

where the real quantities M, P, and μ are defined by

$$Me^{j\mu} = 3x + 2x_0e^{j\pi/6}$$

$$P = \pi/12 - \mu/2 + \frac{5x_0}{2F_1}\,x^2.$$

It is easy to calculate (27), for example by Simpson's rule, as the exponential tends rapidly towards zero. The other integrals are calculated correspondingly.

A slight change in (23) and the similar equations of the preceding sections is required when the stations are higher than the mountain. This case is illustrated in Fig. 3. With the convention chosen in this paper the station "heights" h_1, h_2 and the scattering angle $2\psi_0$ are negative. It is seen from Fig. 3 that nothing has to be changed except the lower limit of the integrals, which is $-\psi_0$ instead of zero; S_1 must always lie on the left and S_2 on the right of plane MAC.

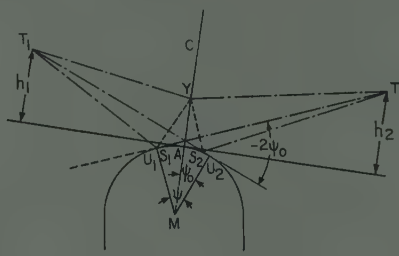

Fig. 3—Stations above the mountain.

Term E_1 may be treated as example.

The substitution

$$\psi = -\psi_0 + \psi'$$

brings the expression $G\psi^2 + F_1\psi^3$ into the form

$$-(F_1\psi_0^3 - G\psi_0^2) + (3F_1\psi_0^2 - 2G\psi_0)\psi' - (3F_1\psi_0 - G)\psi'^2 + F_1\psi'^3. \tag{28}$$

The order of magnitude of the terms of (28) can be estimated by putting $F_1 = 2$ and $G = 5\psi_0$ leading to

$$3\psi_0^3 - 4\psi_0^2\psi' - \psi_0\psi'^2 + 2\psi'^3.$$

For small scattering angles it appears justified to neglect the first two terms in (28) so that the integral reduces to

$$\int_{-\psi_0}^\infty L_1 \exp\left[-jka(G\psi^2 + F_1\psi^3)\right]d\psi = \int_0^\infty L_1 \exp\left[-jka(-H_1\psi_0\psi'^2 + F_1\psi'^3)\right]d\psi \tag{29}$$

with

$$L_1 = \sqrt{(\psi' - \psi_0)(3\psi' - \psi_0)} \tag{30}$$

and

$$H_1 = 3F_1 - 5. \tag{31}$$

To find the complete diffraction curve for a certain radius of curvature it is necessary to calculate the received power $P = EE^*$ for different values of $2\psi_0$. This work is particularly simple when the distances d_1 and d_2 are big enough so that $d_{1,2} \gg 5a\psi_0$. Then (17) and (22) can be replaced by $F_1 = F_2 = F = 2$, and the only parameter on which the integral for E_1 depends is $x_0 = \psi_0\sqrt{2ka}$. Since this holds true also for the other integrals E_2 and E_{12}, some simple algebraic operations are sufficient to calculate the diffraction curve for any ka after the integrals have been evaluated for a series of values of only one parameter, x_0. The calculated results quoted in Section III have been obtained under these simplifying assumptions.

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[12] Born, *op. cit.*, p. 193.

E. Artmann Shift

Both Artmann[13] and Rice[4] predict that the power measured behind a cylinder as a function of scattering angle varies in the same manner as behind a knife edge, except that the edge appears higher or lower depending upon the polarization and radius of curvature of the cylinder. This virtual displacement in height (δ) is given by:

$$\delta = \kappa_{\perp,\parallel}\lambda\left(\frac{a}{\lambda}\right)^{1/3} \tag{32}$$

where $\kappa_{\perp,\parallel}$ is a constant depending upon polarization.

For a comparison of this theory with the theories of Artmann and Rice, it must be kept in mind that these two authors obtain their results under the assumption of an incident plane wave and of a receiver that tends towards infinity. In the notations of this paper

$$d_2 \rightarrow \infty \tag{33}$$

$$d_1 \gg d_2. \tag{34}$$

When the two conditions (33) and (34) are observed, a similar result can be obtained from this theory.

It follows from (33) that the diffraction curves are straight and parallel for the intervals of ψ_0 and ka considered in the following derivation.

Curve 1 of Fig. 4 shows power P against the half scattering angle ψ_0 for knife edge diffraction. The slope ($\tan\alpha$) of this curve can be calculated by differentiation of $P = E_k(\psi_0)E_k^*(\psi_0)$ with respect to ψ_0. With the expression (4) for $E_k(\psi_0)$ it is found

$$\tan\alpha = -\frac{1}{2(d_1+d_2)^2}\sqrt{\frac{2kd}{\pi}}. \tag{35}$$

Curve 2 shows diffraction for a cylindrical mountain. The distance σ between the two curves for $\psi_0 = 0$ is obtained from (38). Assume that d is large enough for the third term in the square bracket of (38) to be neglected, then

$$\sigma = \frac{A_{\perp,\parallel}}{4(d_1+d_2)^2}\cdot\frac{\sqrt[3]{ka}}{\sqrt{\pi kd}}. \tag{36}$$

The Artmann shift $\delta = -2\psi_a d_2$ is obtained from (35), (36) and $\psi_a = \sigma/\tan\alpha$.

$$\delta = \frac{A_{\perp,\parallel}\sqrt[3]{2\pi}}{2\sqrt{2\pi}}\,\lambda\sqrt[3]{\frac{a}{\lambda}}\,\frac{d_2}{d}. \tag{37}$$

From (3) and (34),

$$d = 2d_2$$

which is substituted into (37). Comparing (32) and (37).

$$\kappa_{\perp,\parallel} = \frac{\sqrt[3]{2\pi}}{\sqrt{2\pi}}A_{\perp,\parallel}.$$

With the numerical values for $A_{\perp,\parallel}$ given in (38)

$$\kappa_\perp = +0.316; \qquad \kappa_\parallel = -0.333.$$

If, however, condition (34) is dropped,

$$\kappa_\perp = +0.316(1 + d_2/d_1); \quad \kappa_\parallel = -0.333(1 + d_2/d_1).$$

Hence, the constants κ assume about twice the values calculated above when d_1 and d_2 are of the same order of magnitude.

A table of the values calculated by different authors for κ will be given in Section III in connection with the experimental determinations.

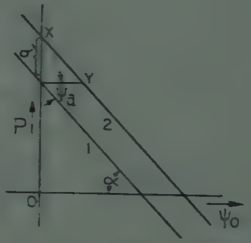

Fig. 4—Derivation of Artmann shift.

III. Experiment

A. Apparatus and Technique

Investigation of diffraction by smooth half-cylindrical mountains and comparison of these results with those of knife edge diffraction have been made by taking measurements on models in the K-band frequency range. The experimental arrangement is shown in Fig. 5. A 2K33 klystron was used as a source of energy, and the oscillator was sufficiently isolated from the transmitting horn by means of a uniline. The transmitted signal, modulated at 1000 cps, was detected by a 1N26 crystal and the rectified signal was fed directly into a Scientific Instruments Automatic Pattern Recorder Model 121. The motion of the receiving probe was directly coupled to the selsyn drive of the recorder so that scans of received power against probe position could be directly obtained. Small horns with very similar patterns in both the E and H planes were used for the transmitting and receiving antennas. The measurements obtained with the receiving horn were checked against those obtained with a dipole and found to be identical for the range of scattering angles investigated in these experiments.

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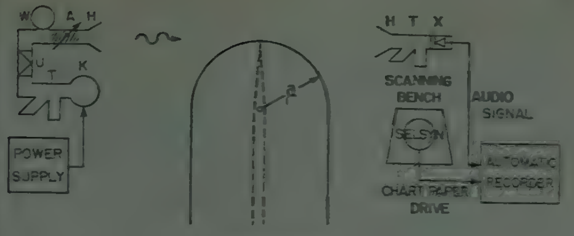
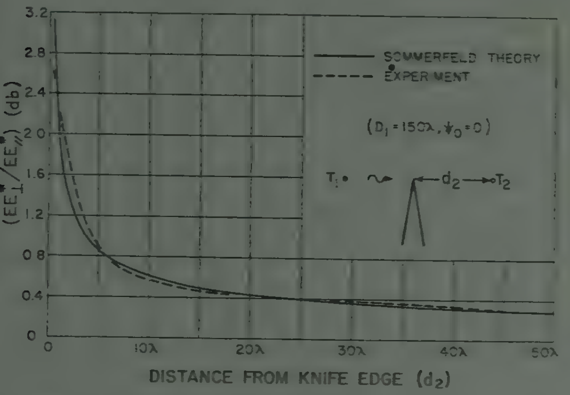
[13] K. Artmann, "Beugung polarisierten Lichtes an Blenden endlicher Dicke im Gebiet der Schattengrenze," *Z. für Phys.*, vol. 127, pp. 468–494; May, 1950.



A = attenuator
H = transmitting horn
K = 2K33 klystron
T = E-H tuner
U = uniline
W = wavemeter
X = crystal.

Fig. 5—Schematic diagram of the experimental arrangement.



g. 6—Ratio of power behind a knife edge at grazing incidence when the electric field is perpendicular to the edge to power behind knife edge when the electric field is parallel to the edge.

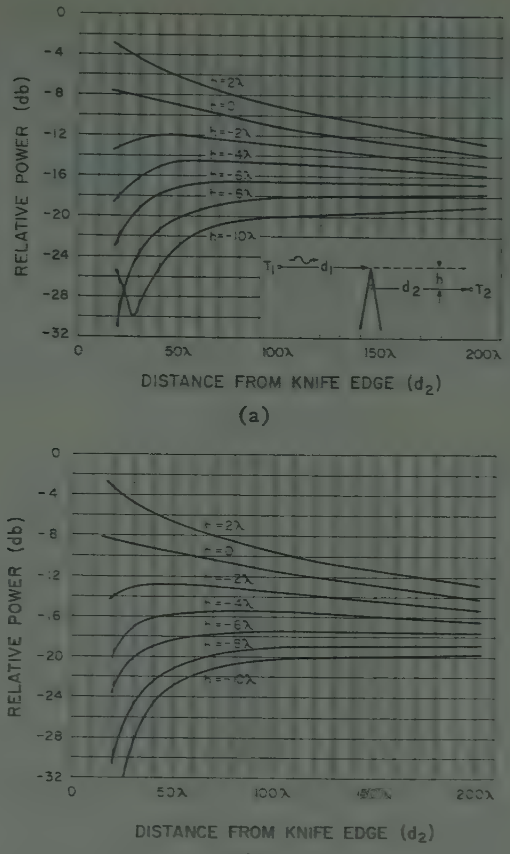
The knife edge consisted of aluminum sheet, 1/16-ch thick while the half-cylinders were constructed om thin, conducting aluminum foil, sufficiently rein-rced to form smooth, cylindrical surfaces. Care was ken to make the knife-edge and cylinders sufficiently ng so that end effects were completely negligible.

Knife Edge

Measurements on a diffracting knife edge served as a mparison for the results obtained experimentally for e cylindrical mountains.

Knife edge diffraction was solved rigorously many ars ago by Sommerfeld.[14] Polarization effects pre-minate only at relatively short distances (measured wavelength) from the diffracting edge. Hence, in tics, due to the extremely short wavelengths, experi-ntal confirmation of Sommerfeld's theory is rare. microwave frequencies, the measurement of the arization effects is entirely feasible. Since to the thor's knowledge no such measurements have been blished, they are included for general interest despite fact that they have little bearing on the main prob- of this paper.

ig. 6 shows the ratio of received power for vertical arization to the received power with horizontal polarization as a function of the distance from the diffracting edge. Comparison with Sommerfeld's theory is in good agreement. At a distance of 50 λ from the edge the difference between the two polarizations is only 0.4 db in power. In addition, the power measured behind a knife edge as function of probe height is shown in Fig. 7(a) and 7(b). Both planes of polarization give similar results when the edge is not approached too closely.



(a)

(b)

Fig. 7—(a) Power distribution behind a knife edge ($ka=0$, $d_1=150\lambda$) for vertical polarization. (b) Power distribution behind a knife edge ($ka=0$, $d_1=150\lambda$) for horizontal polarization.

C. Cylindrical Mountains

The power measured behind a conducting cylindrical mountain of $ka=239$ ($k=2\pi/\lambda$, a = crest radius) is shown in Fig. 8(a) and 8(b). A large difference exists between the two polarizations, particularly when the mountain is approached. For vertical polarization the field is much stronger than for horizontal polarization.

The halo effect is a function of the radius of curvature of the crest (in terms of λ) and of polarization as is shown in the measurements of Fig. 9 which were performed with a series of cylindrical mountains of different radii. For vertical polarization the received power increases with ka, while the reverse is true for horizontal polarization. In addition, the slope of the power variation with scattering (diffraction) angle is essentially the same as for a knife edge in the case of vertical polarization, but becomes steeper with increasing ka for horizontal polari-

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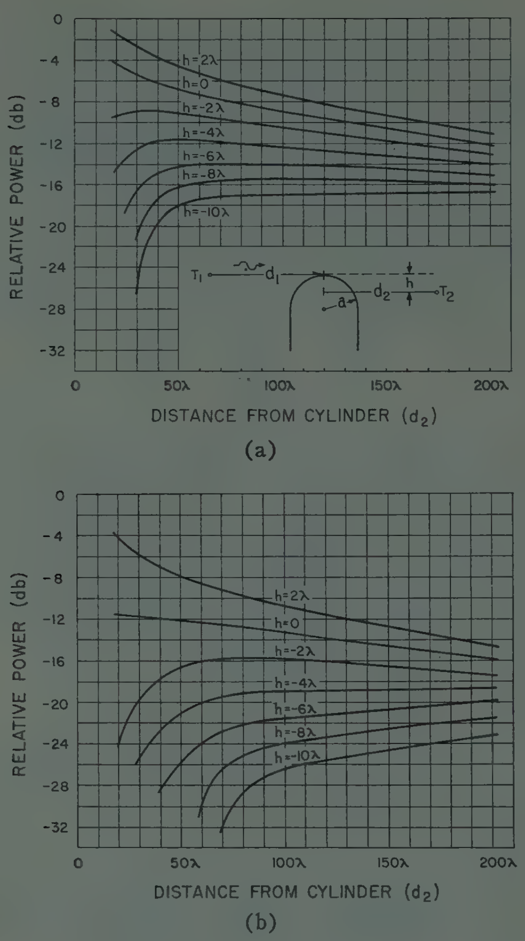
[14] Born, *op. cit.*, pp. 212–215.



(a)

(b)

Fig. 8—(a) Power distribution behind a cylindrical mountain ($ka=239$, $d_1=150\lambda$) for vertical polarization. (b) Power distribution behind a cylindrical mountain ($ka=239$, $d_1=150\lambda$) for horizontal polarization.

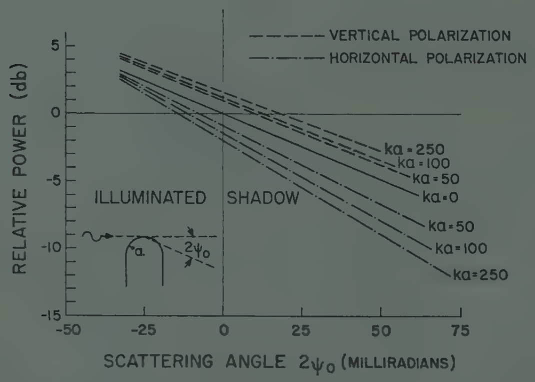


Fig. 9—Variation of power behind a cylindrical mountain with scattering angle as a function of radius of curvature (far field).

zation. Thus in the case of vertical polarization the region behind the mountain is "brighter" than that behind a knife edge; for horizontal polarization, it is "darker."

The power at grazing incidence as the receiver moves away from the cylindrical mountain is shown in Fig. 10 for a crest of $ka=239$. The effect of polarization de-

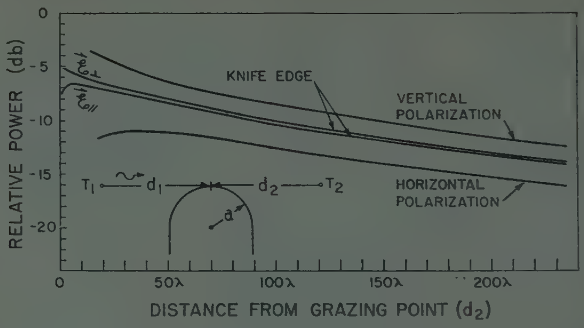


Fig. 10—Power measured at grazing incidence behind a cylindrical mountain ($ka=239$, $d_1=150\lambda$, $\psi_0=0$). Similar measurements behind a knife edge ($ka=0$, $d_1=150\lambda$, $\psi_0=0$) are shown for comparison.

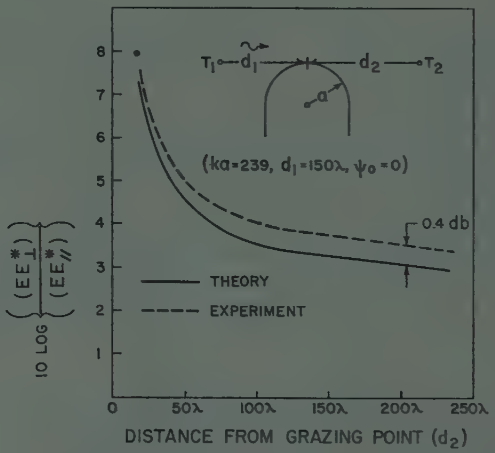


Fig. 11—Comparison of measured and calculated "halo" effects.

creases with distance from the mountain, but is still appreciable, even at 250 λ from the mountain. In comparison the power variation for a knife edge is also shown. For a knife edge the polarization effect is small except near the edge itself.

If $\psi_0=0$ the integrals of (23) reduce to Euler's integrals for the gamma function, and a simple expression for the received power, P, can be obtained.

$$P=(EE^*)_{\perp,\parallel}=\frac{1}{4(d_1+d_2)^2}\left[1+A_{\perp,\parallel}u+B_{\perp,\parallel}u^2\right] \quad (38)$$

with

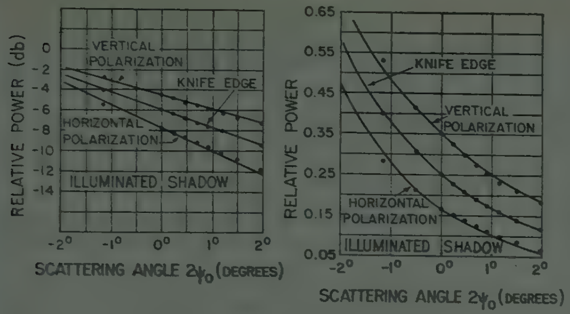
$$u=\sqrt[3]{ka}/\sqrt{\pi kd},$$

$$A_\perp=3.00;\quad B_\perp=2.39;\quad A_\parallel=-3.10;\quad B_\parallel=2.58.$$

Comparison of experiment with theory is shown in Fig. 11 where the ratio

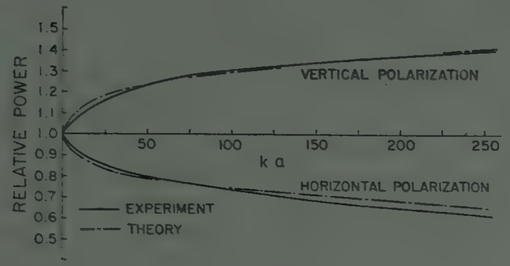
$$10\log\left\{\frac{(EE^*)_\perp}{(EE^*)_\parallel}\right\}$$

is plotted against d_2. Good agreement with theory is obtained, and the spread between the predicted and



(a) (b)

ig. 12—Received power as a function of scattering angle plotted on (a) logarithmic scale and (b) linear scale ($ka=239$, $d_1=150\lambda$, $d_2=113\lambda$). The points (. . .) are theoretical.



ig. 13—Variation of power behind a cylindrical mountain at grazing incidence with radius of curvature of the crest ($d_2=113\lambda$, $d_1=150\lambda$, $\psi_0=0$).

xperimental results is within the limitations of the neasuring equipment. If the received power is plotted s a function of scattering angle, the theory satisfactorly predicts the result over the range of small scattering ngles encountered in practice (Fig. 12). It is evident hat the variation of the power with diffracting angle is nore rapid for horizontal polarization than for vertical olarization.

The power at grazing incidence as determined for a seies of cylindrical mountains (ka values) for the two olarizations is shown in Fig. 13. For vertical polarizaion, the received power at grazing increases with ka; or horizontal polarization, the power at grazing incilence decreases with ka. Agreement with theory is atisfactory along the coordinate for $\psi_0=0$ as well as for mall scattering angle (Fig. 12).

D. Artmann Shift

A comparison of the constants $\kappa_\perp$ and $\kappa_\parallel$ predicted by various authors is shown in Table I. The results derived here are approximately in agreement with those of Rice who considered the special case $d_1 \gg d_2$.

Experimental determinations of these constants have been attempted by: 1) measuring the power behind various cylindrical mountains by vertically scanning with the receiver, and 2) fixing the transmitter and receiver and varying the height of the mountain relative to the transmitter-receiver arrangement. Both of these techniques yielded the same results.

TABLE I

THEORETICAL

Author	$\kappa_\perp$	$\kappa_\parallel$
Artmann	0.20	−0.39
Rice	0.346	−0.399
Theory ($d_1 \approx d_2$)	$0.316\ (1+d_2/d_1)$	$-0.333\ (1+d_2/d_1)$
Theory ($d_1 \gg d_2$)	0.316	−0.333

TABLE II

EXPERIMENTAL ($d_1=120\lambda$, $d_2=80\lambda$)

ka	$\kappa_\perp$	$\kappa_\parallel$
240	0.54	−0.57
192	0.53	−0.54
144	0.52	−0.52
96	0.51	−0.49
48	0.49	−0.44

The experimental values are listed in Table II. The calculated values for these measurements are $\kappa_\perp=0.55$ and $\kappa_\parallel=-0.58$. The experiments show that $\kappa_\perp$ and $\kappa_\parallel$ are not constant for various *ka* values and the more accurate expression (38) should be used. This is a consequence of the fact that for finite distances, the slopes of the diffraction curves are different for each polarization and different from that for a knife edge.

IV. ACKNOWLEDGMENT

The authors' thanks are due to R. Cajka for his help with the calculations and to Dr. I. Shkarofsky for a critical perusal of the manuscript which led to a number of corrections and improvements.

* * *

Refraction Anomalies in Airborne Propagation*

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Summary—Propagation at 250–10,000 mc often encounters: 1) dense fadings where the radio signal fluctuates spatially with large amplitudes and small spacings from maxima to minima, *e.g.* amplitudes of up to 40 db and spacings at 3000 mc of 1 mile; 2) radio holes, where the signal falls spatially to a level often 15 db or more below the levels outside; 3) antiholes, where the signal fluctuates spatially with large amplitudes and irregular spacings; 4) radio ducting, including cases where the transmitter or receiver is far above a ducting layer in the air.

The anomalies (1–4) are portrayed by ray tracings using a differential analyzer which solves the simplified ray equation

$$\frac{d^2h}{dx^2} \cong \frac{\partial n(h, x)}{\partial h} + \frac{1}{a}.$$

Both hypothetical-prototype and complex-measured refractive index profiles of the atmosphere are used for the analog computation of the ray tracings which are interpreted to explain refraction anomalies in radio-wave propagation and are compared with signal-strength measurements. They involve divergence of rays, and concentration and crossing of direct rays in multipath transmission. Resulting radar angular and range errors are shown where the radar sights a target at a) multiple elevation angles, of under 1 degree, which deviate by up to few tenths of a degree from the angle obtained if the atmosphere were standard, and b) multiple range corrections, for a 200-mile range, which deviate by few tens of feet from the standard correction. Also shown are spatial variations of elevation angles of arrival of interfering rays at the points where they cross—variations showing differences of 0.15 degree between the envelopes of angle-of-arrival maxima and minima, at small angles; this corroborates radio-astronomical data on angular deviations of stars.

I. INTRODUCTION

MEASUREMENTS with refractometers often show layers and smaller refractive-index inhomogeneities in the air.[1] These are due usually to water-vapor variations, and found mostly in the lowest 10,000 feet of air. Radiosonde-weather data show that in Ohio, layers occur from 20 per cent of the time for January to 60 per cent for July.

Anomalies which result from atmospheric refraction of radio waves have been extensively observed in airborne propagation at 250–10,000 mc. WADC has studied their correlations with atmospheric refractive-index conditions, on a prevailing cause-and-effect basis, in more than 50 air-to-air propagation flights in Ohio and in some ground-to-air flights in Florida. Radio holes and concomitant antiholes, occurring from anywhere far within to far beyond the standard (4/3)-earth horizon, are the prominent and frequently occurring anomalies air-to-air. Dense-radio fadings and extended ducting effects are the important ones ground-to-air; holes far within the standard horizon have been observed (by W. M. Browne[2]) in ground-to-air propagation also, but these require rather special conditions as shown in Section VI.

Observations on the anomalies have been made also in point-to-point propagation links.[3–6] Thus, aside from data on spatial variations of radio-field intensity in airborne propagation, there are extensive data measured as functions of time on signal fadings, frequency selectivity of fadings, multiple angles of arrival and path delays of interfering signals. Bean observed "prolonged space-wave fadeouts";[6] these represent the first report of radio holes within the standard horizon in propagation between low- and high-altitude points (between ground and mountain top), corresponding to the airborne radio holes. The anomalies occur in propagation over land and sea. They are not (at least they have not been observed to be) dependent on radio-wave polarization.

First explanations for radio holes were given by Doherty[7] and Price.[8] Ray theory, especially ray tracing,[9] is well adapted to handle this problem.

The categories of anomalies so far observed in propagation are portrayed by ray tracings in Section VI. Current ray-tracing techniques—using electronic differential analyzers, and building on techniques of Hartree, *et al.*[10] are well able to handle atmospheres where the refractive index varies with distance as well as height. Atmospheres which vary only with height suffice to cause serious anomalies air-to-air; only atmospheres which vary with both height and distance can cause any anomaly at all ground-to-air.

The ray tracings in Section VI comprise ray patterns, and results on initial angles, angles of arrival, relative

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[1] C. M. Crain, "Survey of airborne microwave refractometer measurements," PROC. IRE, vol. 43, pp. 1405–1412; October, 1955.

[2] C. H. Duerfeldt, "Propagation in the 328–2300 Mc Frequency Band," Naval Air Test Center, Patuxent River, Md., Rep. No. EL 44012.3, pp. 10–17; October, 1954.

[3] A. B. Crawford and W. C. Jakes, "Selective fading of microwaves," *Bell Sys. Tech. J.*, vol. 31, pp. 68–90; January, 1952.

[4] O. E. De Lange, "Propagation of very short microwave pulses," *Bell Sys. Tech. J.*, vol. 31, pp. 91–103; January, 1952.

[5] J. P. Day, R. U. F. Hopkins, and L. G. Trolese, "Symposium on Tropospheric Radio Propagation within the Horizon," Navy Electronics Lab., San Diego, Calif., Rep. No. 409, pp. 43–50; September, 1953.

[6] B. R. Bean, "Prolonged space-wave fadeouts at 1046 mc," PROC. IRE, vol. 42, pp. 848–853; May, 1954.

[7] L. H. Doherty, "Geometrical Optics and the Field at a Caustic," Ph.D. Dissertation, Elec. Eng., Cornell Univ., Ithaca, N. Y.; 1952.

[8] W. L. Price, "Radio shadow effects produced in the atmosphere by inversions," *Proc. Phys. Soc. London*, vol. 61, pp. 59–78; July, 1948.

[9] C. R. Burrows and S. S. Attwood, "Radio Wave Propagation," Academic Press, New York, N. Y., pp. 138–150; 1949.

[10] D. R. Hartree, J. G. L. Michel, and P. Nicoloson, "Metorological factors in radio propagation," *Proc. Phys. Soc. London*, pp. 127–169; 1946.

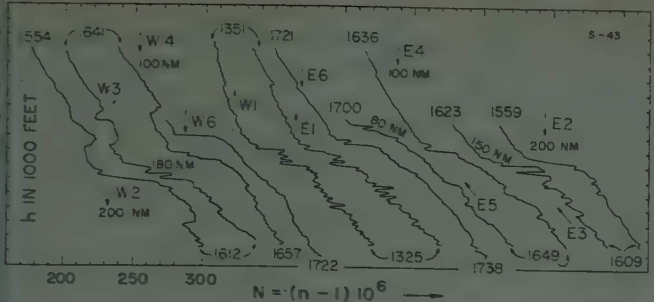


Fig. 1—Refractivity vs altitude profiles: W6, W1, E1, E6 are for Dayton, Ohio; W2–W4 for distances given in nautical miles (NM) to the west; E2–E5 for distances to the east. (May 20, 1953.)

phases, and ray-path corrections of the rays in these patterns. The patterns show spatial distribution of rays being refracted in various prototype and complex atmospheres. Though representing only time-stationary or "snap-shot" views of changing events, the patterns successfully correlate with radio field-intensity variations in airborne propagation; they consistently identify the occurrences, types, and locations of the anomalies. The other results are relevant to and corroborate radar angular and range errors, radio-astronomical data on angular deviations of stars, atmospheric corrections for velocity-of-radio-wave measurements, and appearances of multiple pulses on the output scope in air-to-air operation of Shoran.

With ray tracings, interpretations for the anomalous effects of atmospheric refraction observed in the point-to-point propagation links[3–6] are also apparent.

II. REFRACTIVE-INDEX PROFILES

Fig. 1 shows an example of N vs h profiles at different times and places; $N=(n-1)10^6$ is the refractivity, n the index of refraction, and h the altitude above sea level. Appearing in west-east order, the profiles were measured by refractometers in two airplanes—one flying vertical spirals and slanting paths (shown by the vertical and slanting arrows) to measure the profiles west of Dayton, the other doing the same east of Dayton. The 4-digit numbers on the profiles denote times.

An extensive layer is seen where N decreases rapidly with h for large net changes of about 40 N units. This layer is a few hundred feet thick, and lies between 6000 and 9000 feet. Though the altitude, thickness, and net change in N all vary with distance and time, the layer has a recognizable identity throughout the 400-mile path and 4-hour duration of the flight. The profiles for Dayton show strong wiggles at the beginning of the flight—wiggles which prevailed at heights below the layer, which later cleared away, and which represent small-size refractive-index inhomogeneities with changes in N of up to 10 N units or more.

Fig. 1 illustrates some of the atmospheric situations treated in Section VI.

III. DENSE FADINGS

Dense fadings are shown in Fig. 2 (due to Browne[2]). They are rather common in ground-to-air propagation, but are likely to be obscured by commonly occurring antiholes in air-to-air propagation.

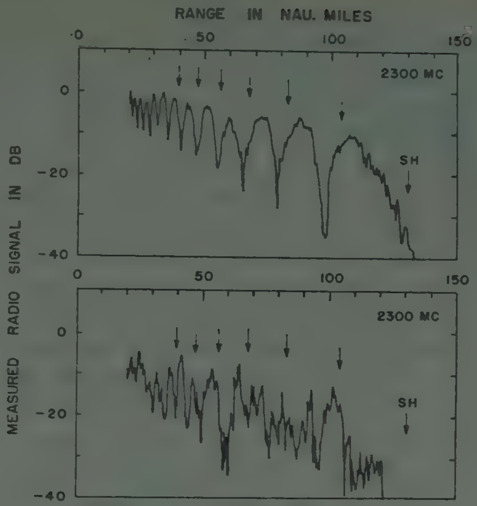


Fig. 2—Signal vs range curves on different days at 10,000-foot altitude in ground-to-air propagation over Chesapeake Bay. Top curve nearly standard, bottom shows mild case of dense fadings. (W. M. Browne data.[2])

In Fig. 2 the curves were measured on separate days—both at 2300 mc, with CW transmission, vertical polarization, 35-foot transmitting height, and 10,000-foot receiving-airplane height over Chesapeake Bay. The arrows denote locations of signal minima in the standard lobing curve for interference between direct and reflected signals in the standard atmosphere over spherical earth. The top curve is nearly standard. The bottom curve shows a mild case of dense fadings—where the signal fluctuates spatially with considerable amplitudes, and with the minima more closely spaced than in the standard curve. Curves measured at 328 and 1186 mc, simultaneously with 2300 mc and omitted here, show comparable fading amplitudes.

Dense fadings more severe than in Fig. 2 have been observed—with fading amplitudes of up to 40 db from signal maxima to minima, in distance spacings of 1 mile at 3000 mc.

Figs. 9 and 10 will show that horizontally varying layers and smaller refractive-index inhomogeneities provide atmospheric causes for dense fadings. Nonspecular reflections at the earth's surface provide another type of cause.

IV. RADIO HOLES AND ANTIHOLES

Radio holes and antiholes occurring far from within to far beyond the standard horizon (*SH*) are very common air-to-air. All of the 50 air-to-air propagation flights made by WADC encountered radio holes; these flights were all made under fair weather during May–October in a three-year period in Ohio. Holes far within the *SH* are not so common ground-to-air. Until they were first observed by Browne (Fig. 4), it was reasoned that holes could not occur far within the *SH* in ground-to-air propagation.

In Fig. 3, the signal vs range curve was measured air-to-air at 3296 mc, with horizontal polarization, pulse modulation, and with the transmitting and receiving airplanes flying opposite headings at 10,000 feet above sea level on a west-east path. The center of separation between the airplanes remained within a few miles of Bellefontaine, Ohio, where ground is near 1250 feet above sea level. The dashed curve represents inverse-distance (D^{-1}) field intensity. There is a pair of hole (where the signal falls below the signal levels outside) and antihole (where the signal is enhanced and fluctuates spatially) within the standard horizon *SH*, and a second pair far beyond the *SH*. The signal in the second antihole rises to within few decibels of inverse-distance field intensity, and is several tens of decibels above the signal level due to atmospheric scattering or reflection.

The ray-density curve in Fig. 3 is given by ray tracings in Figs. 11(a), (b), and is based on in-flight measurements of refractive index vs height profiles. Good correlation is shown with the radio-signal curve; the circumstances were favorable in that the index profiles showed good stability with respect to time and distance along the propagation path.

Holes wider and deeper than those in Fig. 3 have been observed, sometimes with signal losses of 30 db or more.

In Fig. 4 the curves were measured ground-to-air simultaneously—at 328 mc with CW transmission from 70-foot transmitting height, 1186 mc with pulse modulation from 70-foot height, and 2300 mc with CW from 35-foot height. All three frequencies used vertical polarization; the receiving airplane flew at 10,000 feet over Chesapeake Bay. A deep radio hole, 30 miles wide, is seen far within the standard horizon *SH* at 1186 and 2300 mc. The hole is hardly noticeable at 328 mc. This presumably is because reflections by the Bay were specular, and thus gave considerable reflected signal in the hole, at 328 mc but were nonspecular and diffusely scattered at the two higher frequencies.

Fig. 12 will show that a wide radio hole can be produced far within the standard horizon, ground-to-air, by a strong layer which rises steeply from near the transmitter for several hundred feet of height and then levels off with distance. Such a layer occurs with incoming sea breeze.

In a radio hole, both the direct and earth-reflected signals must be weak. Thus reflections by land must often, and by sea must sometimes, be nonspecular and diffusely scattered such as to give only weak signals in the holes.

Propagation measurements at spot frequencies in the 250–10,000 mc band show that, except when affected by reflections from the earth's surface, the occurrences and locations of radio holes and antiholes do not in gross features depend on frequency in the band concerned. On entering and leaving a hole, the signal falls and rises at spatial rates which increase with frequency. In antiholes, the distance spacings between signal minima decrease with frequency.

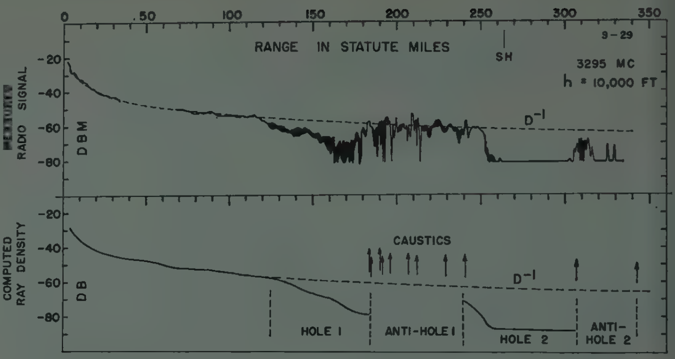


Fig. 3—Signal vs range curve at 10,000-foot altitude in air-to-air propagation, and ray-density curve computed from *N*-profile data. Holes and antiholes occur within and far beyond standard horizon. (Ohio, May 15, 1951.)

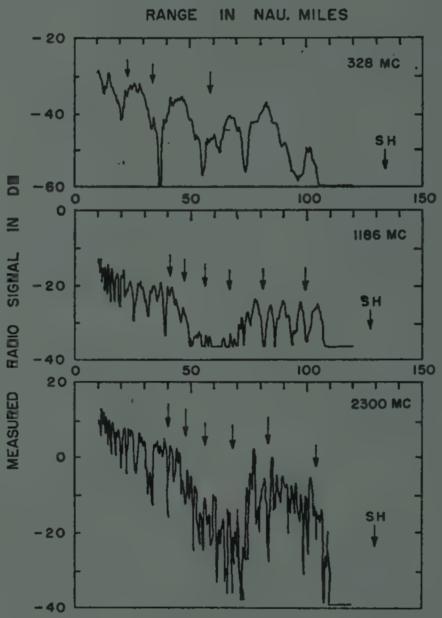


Fig. 4—Simultaneous signal vs range curves at 10,000-foot altitude in ground-to-air propagation over Chesapeake Bay. The hole so far within the standard horizon is unusual ground-to-air. (W. M. Browne data.[2])

V. Ducting

Figs. 5 and 6 show the spatial variations of radio-field intensity, respectively, within a horizontally varying duct, and at a great height above a leaking duct.

In Fig. 5 the signal vs range curve was measured at 250 mc, with vertical polarization, square-wave modulation, and with the transmitting and receiving airplanes flying opposite headings at 10,000 feet above sea level on a west-east path. The center of separation between the airplanes remained within a few miles of Dayton, where ground is near 1000 feet above sea level. There are two wide-distance intervals where the signal falls deeply below inverse-distance (D^{-1}) field intensity, where the signal envelopes are cusp-shaped with pointed minima. These intervals are not accompanied by antiholes. Outside these intervals, where the signal is high and near inverse-distance field intensity, only small-

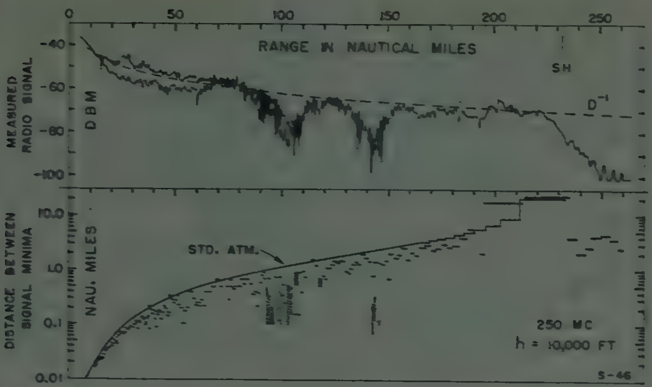


Fig. 5—Signal vs range curve at 10,000-foot altitude in air-to-air propagation, and curve of distance spacings between signal minima. The wide, cusp-shaped minima are due to interference of trapped and nontrapped rays in a radio duct. (Ohio, July 29, 1953.)

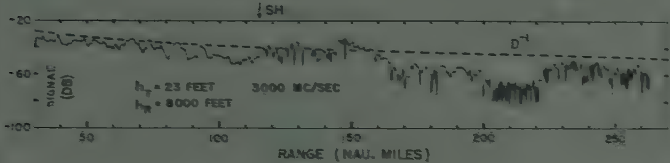


Fig. 6—Signal vs range curve at 8000-foot altitude in ground-to-air propagation over the Atlantic from Florida. Signal continuing on beyond *SH* is due to rays escaping from a thin duct at ocean surface. (May 23, 1956.)

amplitude fadings occur—instead of large-amplitude fadings which characterize antiholes. Fig. 13 will show that the transmitting and receiving airplanes were within a duct.

In the lower half of Fig. 5, the solid curve, superposed on the measured values of distance spacings between signal minima, represents interference between direct and reflected signals in the standard atmosphere over spherical earth. The decreased distance spacings between signal minima, in the figure, include effects of interference between rays which are trapped in the duct and rays which are not trapped.

Fig. 6 was measured at 3000 mc, with pulse modulation, vertical polarization, 23-foot transmitting height in Cape Canaveral, Fla., and 8000-foot receiving height over the Atlantic. The curve is very notable in its extended range. The signal is up to inverse-distance field intensity in a 45-mile interval beginning at the standard horizon *SH*, and is within several decibels of inverse-distance field intensity in a second 45-mile interval beginning 105 miles beyond the *SH*. Fig. 14 will explain this with rays initially trapped in a thin layer just above the ocean surface, and then progressively escaping at various distances through the top of the layer.

VI. Ray Tracings

Fig. 7 through Fig. 15 show ray tracings under various atmospheric conditions, under Cases A–H below.

In each ray pattern, h is height above an arbitrary level, and x is spherical-earth distance. The dN/dh vs h profile shown is for $x=0$, and varies with x in most cases; the scale for dN/dh, the vertical gradient of $N=(n-1)10^6$, is in N-units per foot (in units of 10^{-6}/foot for dn/dh). The transmitter emits rays in various directions within a beamwidth of initial elevation angles labeled on the rays. The rays are continually being refracted (bent) in the air; they may be viewed as trajectories of the normals to radio-wave fronts, *i.e.*, as paths followed by radio waves in the plane of propagation concerned.

The equation for tracing rays in an atmosphere where the index of refraction, n, varies with height and distance is

$$\frac{d^2h}{dx^2} \simeq \frac{\partial n}{\partial h}(h, x) + \frac{1}{a}. \qquad (1)$$

Here a is the earth's radius ($1/a=0.048\times10^{-6}$/foot); the standard atmosphere has $dN/dh=-0.012\times10^{-6}$/foot. Eq. (1) is derived from Fermat's principle, and simplified for rays with elevation angles within ±6 degrees. Each ray is a solution of (1) for given initial values of h (transmitter height) and dh/dx (angle of the ray at transmitter). For each ray pattern, (1) is solved and the rays are traced by electronic differential analyzers. The method of doing this is described in the Appendix.

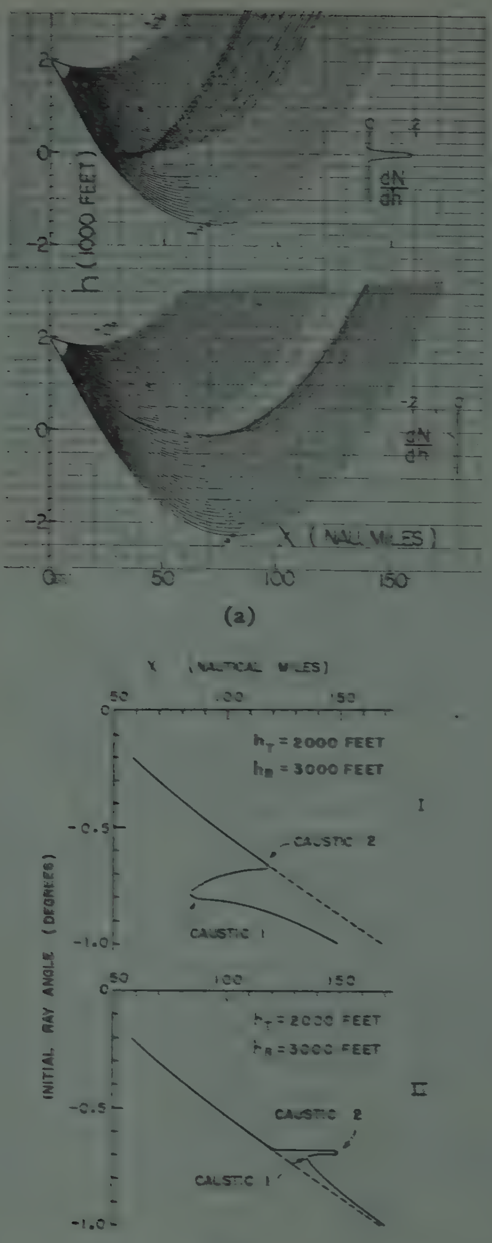
Plotting h and x on rectangular axes, for convenience, causes the rays in the patterns to have an apparent curvature which is given, according to (1), approximately by ($\partial n/\partial h+1/a$), and which differs from the true curvature. For example, consider the rays in the standard atmosphere: physically, these rays have a slight, negative true curvature; in a pattern, these rays would appear as parabolas with a positive apparent curvature (see the standard rays in parts of Fig. 7(a). The transformation of curvature does not matter in the correlations, below, between ray tracings and the propagation effects they portray.

A. Horizontal Layer

Fig. 7(a): The dN/dh vs h profiles do not vary with x; dN/dh has a positive peak for the layer in the top pattern, and a negative peak in the bottom.

The rays lying entirely above either layer are standard. In the top pattern the rays which graze the layer—those which travel down to the layer, and then turn upward with turning points inside the layer—are bent backward with respect to the up-going trajectories of the standard rays. In the bottom pattern the layer-grazing rays are bent forward. The rays which turn upward with turning points below either layer become progressively less affected.

In general, the ray-scarce areas in the ray patterns—which show only direct rays, and which (except Fig. 15) omit reflections of rays by the earth's surface—would give rise to radio holes provided the reflections do not give appreciable signals in the areas concerned. This has been found to be true in propagation over land many times, and over the ocean sometimes. The ray-crossing



(a)

(b)

Fig. 7—(a) Ray patterns each with a ray-scarce and ray-crossing area (radio hole and antihole). Transmitter is above horizontal layer with positive dN/dh peak at top, negative dN/dh peak at bottom. (b) Diagrams of initial angles of rays vs their intercept distances at $h=3000$ feet in (a).

areas give rise to antiholes regardless of reflections, as a result of interference of the crossing rays.

Depending on the position of the transmitter, the effects of a horizontal layer are as follows: If the dN/dh peak is negative, and when the transmitter is anywhere above the layer, there occurs a hole followed by an antihole; when it is within or just slightly below the layer, there occur a horizontal duct along the layer, and a hole and antihole above the layer; when it is farther below the layer, no hole, antihole, or duct occurs. If the dN/dh peak is positive, there occurs an antihole followed by a hole—provided the transmitter is anywhere above, or within the layer.

The holes and antiholes curve upward without ending. To cause them, a layer need not extend more than a few tens of miles in distance.

From the above it is clear that horizontal layers can cause serious anomalies in air-to-air propagation (where the layers are apt to prevail below the transmitter); they can cause only subdued effects ground-to-air (layers above transmitter).

In Fig. 7(b) each diagram plots the initial angles of individual rays vs the distances, X, where the rays intercept a chosen horizontal path at the height $h_R=3000$ feet in one pattern of Fig. 7(a). The dashed curves are for the standard atmosphere.

The slope of a diagram of initial angles A_T of rays vs their intercept distances X, for a chosen path at height h_R, gives a measure of ray density. Consider two A_T vs X diagrams—one for an actual atmosphere, the second for the standard atmosphere, both for the same chosen path at height h_R and the same transmitting height. Then the square root of the ray-density ratio,

$$R(X; h_R) = \frac{\text{slope at distance } X \text{ of first diagram}}{\text{slope at distance } X \text{ of second diagram}}, \quad (2)$$

corresponds with the ratio of actual radio-field intensity to inverse-distance field intensity. This is valid at all points not too close to caustics where ray density is infinite.

The caustics appear in ray patterns as loci of dense-ray concentration; they are envelopes formed by intersections of consecutive rays.

Fig. 7(b) shows that each caustic is tangent to a serpentining U turn in the A_T vs X diagrams. The two arms of each U turn represent two groups of direct rays, one group crossing and interfering with the other. The space on one side of the caustic (the visibility side, where the U lies) is doubly traversed by the rays of the U concerned; the space on the other side of the caustic (the shadow side, where the U points away from) does not contain any rays of the U. Thus the resultant ray density, due to the rays of the U concerned, is zero on the shadow side, jumps to infinity at the caustic, then oscillates spatially with decreasing amplitude on the visibility side. This ray-theory picture is subject to a slight modification by wave theory, which gives the Airy type of result for caustics.[1,11] This modification—which can be obtained also be combining the ray tracings here with the known theory for caustics in *homogeneous* media—consists in giving a finite maximum of radio-field intensity near the caustic, and in giving an exponentially attenuated field intensity in place of the zero-ray density at the shadow side.

On the view that radio waves are propagated along rays, the apparent elevation angle of a target observed by radar is given by the initial angle of the ray which intercepts the target. Thus deviations and multiplicities

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[11] G. B. Airy, "Intensity of light in the neighborhood of a caustic," *Proc. Cambridge Phil. Soc.*, vol. 6, pp. 379–401; May, 1838.

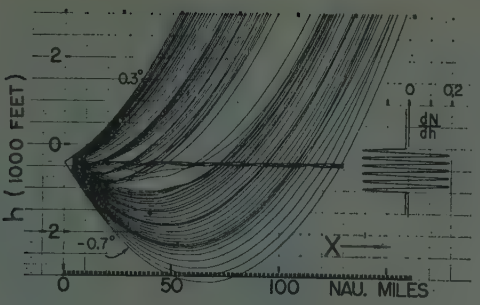


Fig. 8—Pattern with holes, antiholes, and horizontal duct. Transmitter is at a negative dN/dh peak in 1000-foot stratum of layer fragments.

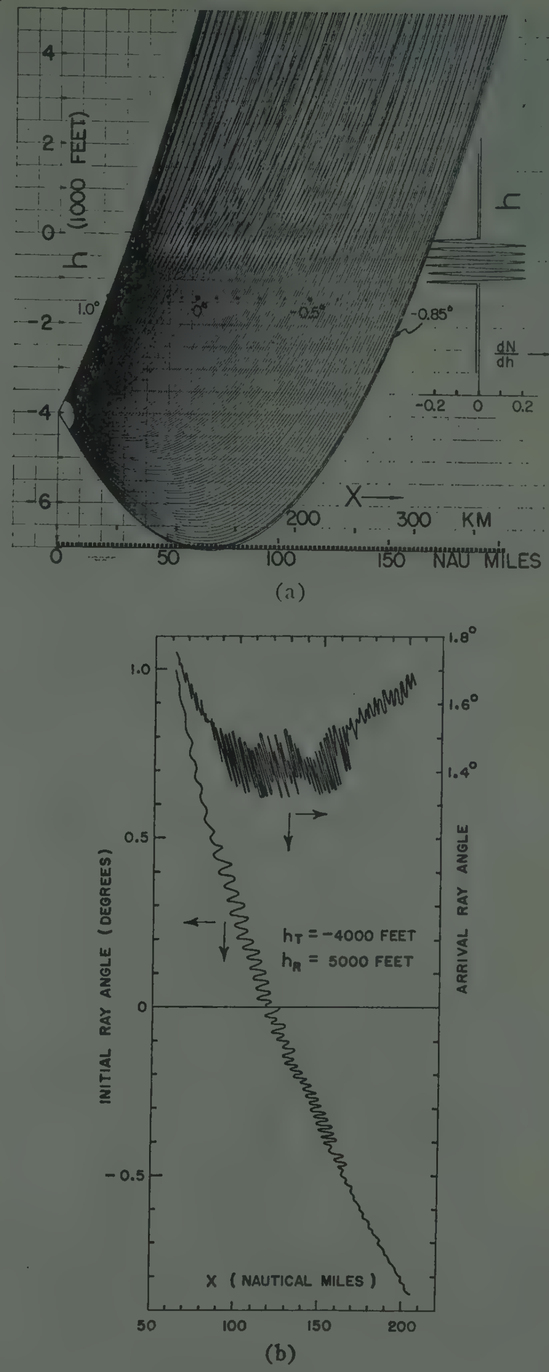
of radar-elevation angles are involved in antiholes. In the upper diagram of Fig. 7(b), an airborne radar would sight a target at two elevation angles, -0.45 and -0.8 degree, when the target is at the range of the first caustic. The second angle, of -0.8 degree, occurs at a range which departs from the standard range by 60 miles.

B. Stratum of Layer Fragments

In Figs. 8 and 9, dN/dh varies as a function of h with negative and positive peaks inside a stratum 1000 feet thick. The dN/dh vs h profile applies over alternate 1-mile intervals of distance marked by shadings near the x-axis of each ray pattern; dN/dh is standard in the intervening miles of the stratum, and also above and below the stratum. The change in N under each dN/dh peak is 10 N units. A layer fragment is obtained with each dN/dh peak in the stratum. The fragments thus obtained—each 91 feet thick, and extending 1 mile horizontally—have discontinuous changes of dN/dh across their vertical boundaries, and simulate refractive-index inhomogeneities in the air.

In Fig. 8 the dN/dh peaks above the transmitter do not produce any holes. The negative peak where the transmitter is located (the fifth peak from the top)—though the dN/dh profile is interrupted at 1-mile intervals—traps some rays in a duct; it, together with the 6th peak, causes the first narrow pair of hole and antihole above the duct. The 7th and 8th peaks act in unison, and give the second narrow pair of hole and antihole; the 9th and 10th peaks give the third narrow pair. The 11th peak, not counteracted by a lower positive peak, gives the fourth and wide hole which is followed by the wide (last) antihole.

In Fig. 9(a) dense-ray crossings—with closely spaced alternations of ray scarcity and concentration, and closely spaced caustics—take the place of radio holes and antiholes as soon as the transmitter is far enough below the layer fragments for ducting to cease. The dense crossings occur even when the transmitter is thousands of feet below the layer fragments. If the dN/dh vs h profile were to remain constant with x, no ray crossings would occur whenever the transmitter is below the dN/dh peaks.



(a)

(b)

Fig. 9—(a) Pattern with dense-ray crossings associated with dense-radio fadings (Fig. 2). Transmitter is far below 1000-foot stratum of layer fragments. (b) Diagrams of initial angles and angles of arrival of rays vs their intercept distances at $h=5000$ feet in (a).

Fig. 9(b) shows diagrams of initial angles and angles of arrival of individual rays vs the distances, X, where the rays intercept a chosen horizontal path at the height $h_R=5000$ feet in Fig. 9(a). The initial-angle diagram makes serpentining U turns with closely spaced caustics; it shows that a radar, even when situated thousands of feet below the stratum, may sight a target above the stratum at multiple elevation angles with differences of up to 0.1 degree. The angle-of-arrival diagram shows multiple-valued branches which fluctuate spatially with differences of up to 0.15 degree between the envelopes of angle-of-arrival maxima and minima: this corroborates the deviations due to atmospheric refraction, observed in the elevation angles of arrival of radio stars.[12]

The angles of arrival, A_R, of individual rays serve also to determine their relative path delays, and thus their relative phases. With Fermat's principle it can be shown that the relative phases of individual rays, as a function of the distances X where the rays intercept a chosen horizontal path at the height h_R is given by

$$\phi(X; h_R) = \frac{2\pi}{\lambda}\left(1 + \frac{h_R}{a}\right)\int_{X_1}^{X} n(X; h_R) \cdot \text{Cos } A_R(X; h_R)dX. \quad (3)$$

Here $A_R(X; h_R)$ denotes a single-valued branch of the A_R vs X diagram for the chosen path; λ is the wavelength; a the earth's radius; n the index of refraction; X_1 is a distance chosen as the reference for zero phase. By taking X_1 near the values of X concerned, (3) gives accurately the relative phases of the rays in each single-valued branch of an A_R vs X diagram. Eq. (3) is important in that the alternative procedure of computing first the enormously large path lengths of the rays concerned, and then their small differences to obtain the phases, is inaccurate.

The dense-ray crossings in Fig. 9(a) cause dense-radio fadings—as a result of the closely spaced caustics, and attendant interference of groups of rays. Each of these groups of rays corresponds to, and has a ray density determined by, a single-valued branch of an A_T vs X diagram; the rays of one group interfere with those of the other groups. The phases of the interfering rays at a ray-crossing point are given by (3).

Dense-ray crossings can be caused even with just a single layer where the peak of the dN/dh vs h profile varies continuously and gradually as a function of x; this is shown in the next case.

C. Layer Varying Sinusoidally with Distance

In Fig. 10 the height, h_c, of the layer varies sinusoidally with x; the maxima of h_c depart only 100 feet from the mean, in distance of 1.25 miles. This variation of h_c is moderate for layers over an ocean.[13] The amplitude, P, and the shape of the dN/dh vs h peak does not vary with x; the change in N through the layer is 40 N units. The dense-ray crossings shown can be produced also by causing only the amplitude of the dN/dh peak to vary sinusoidally with x.

With the atmospheric situations in Figs. 9 and 10, the dense-ray crossings occur when the transmitter is anywhere above, within, or even far below the layer fragments or the horizontally varying layer. For any of these transmitter positions, the rays which intercept the layer fragments or the layer at sufficiently small elevation angles, all have their up-going trajectories involved in ray crossings; these crossings extend from, and to all heights above, the layer fragments or layer.

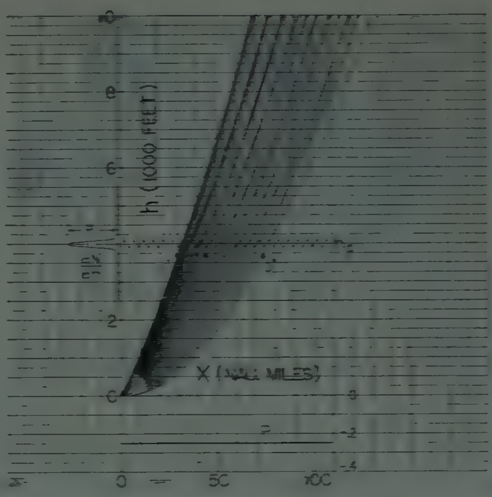


Fig. 10—Pattern with dense-ray crossings associated with dense-radio fadings (Fig. 2). Transmitter is far below layer which varies sinusoidally with distance.

D. A dN/dh Profile Measured with Propagation

In Fig. 11(a) the dN/dh vs h profile is computed from one of the three N profiles, all essentially alike, which were measured at different times and places along the air-to-air propagation path in Fig. 3; the dN/dh profile is presumed not to vary with x.

If the atmosphere were standard, the tangent ray (the ray which grazes the earth's surface from the transmitter) constitutes the farthest-reaching ray; in Fig. 11(a) it would reach 264 miles at $h=10{,}000$ feet, with the ground at $h=1250$ feet. With the dN/dh profile shown, the actual tangent ray reaches 307 miles; yet, it does not reach as far as other rays in the last antihole. This antihole, which has appreciable ray densities between 306 and 346 miles at $h=10{,}000$ feet, is due to the layer near $h=2000$ feet. The rays which graze this layer, because its dN/dh peak has values near $-1/a$, pursue nearly horizontal trajectories for large distances—with "flat bottoms" near the layer—before turning upward and intersecting one another to form the last antihole; hence the very wide hole preceding it.

The densities of rays along the horizontal path at $h=10{,}000$ feet in Fig. 11(a)—as determined by (2), and the slope of the initial-angle diagram in Fig. 11(b)—give the ray-density curve in Fig. 3, the curve in favorable correlation with the measured radio-field intensity.

In Fig. 11(b), the diagrams show the initial angles and range corrections of individual rays vs the distances, X, where the rays intercept a chosen horizontal path at the height $h_R=10{,}000$ feet in Fig. 11(a). (The initial-angle diagram in this case represents also the negative of the angle-of-arrival diagram of the rays, for the same intercepting height.) The range correction for each ray is computed as

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[12] J. L. Pawsey and R. N. Bracewell, "Radio Astronomy," Oxford University Press, New York, N. Y., pp. 342–344; 1955.

[13] E. Gossard and W. Munk, "Gravity waves in the atmosphere," *J. Meteorology*, vol. 11, pp. 259–269; August, 1954.

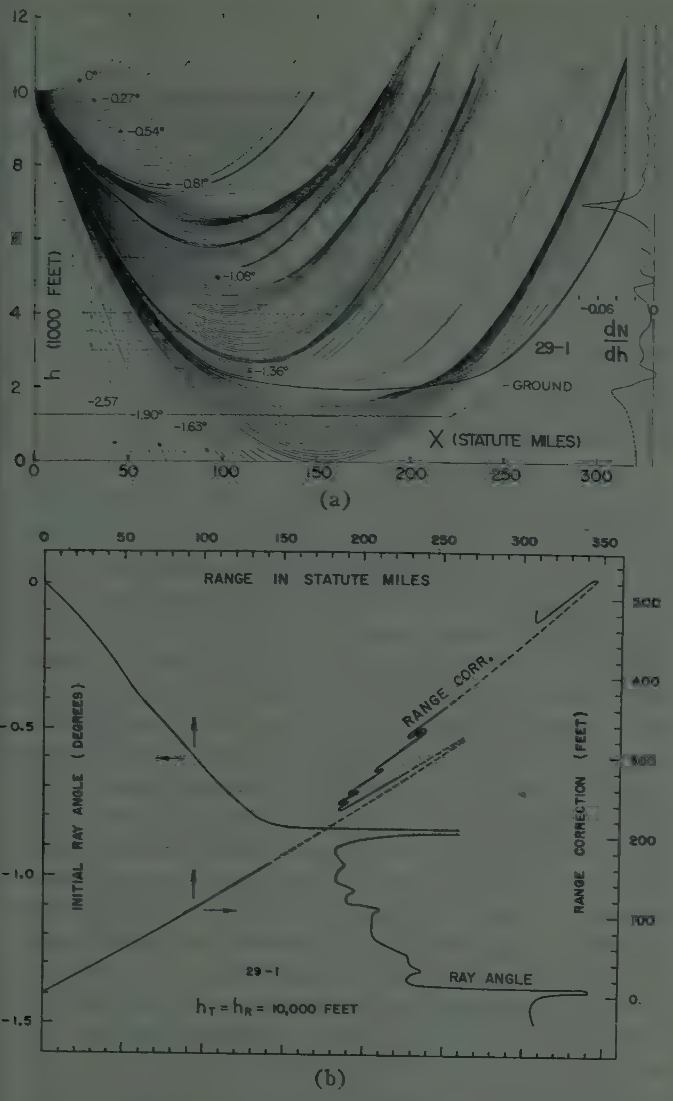

Fig. 11—(a) Pattern with holes and antiholes which correlate with Fig. 3. dN/dh profile is based on measurements during propagation. (b) Diagrams of initial angles and range corrections of rays vs their intercept distances at $h = 10,000$ feet in (a).

$$\Delta S(X; h_R) = \int_{(0;h_T)}^{(X;h_R)} (n - 1)dS \qquad (4)$$

where the integration is along the ray from transmitter to the point (X, h_R), $n(x, h)$ is the index of refraction, and dS is an element of arc length. Eq. (4) gives the difference between the ray path traversed by radio waves in vacuum and the path traversed in the actual atmosphere concerned—for the same time duration, and same initial angle of the ray; it gives accurately the corrections for atmospheric effects in measurements on the velocity of radio waves.[14]

The diagrams in Fig. 11(b) show multiple-valued branches in the antiholes, each branch corresponding to a group of rays intersecting with other groups; as many as four groups, each with high ray density, intersect one another near $X = 190$ miles. Thus a radar sights a single target at multiple elevation angles, and multiple ranges; and interfering rays reach a receiving point at multiple angles of arrival. At a ray-crossing point, counting only rays of high density, the multiple angles have mutual differences of up to 0.15 degree; the multiple range corrections show ray-path differences of up to 10 feet or more. The initial-angle diagram deviates from the corresponding diagram for the standard atmosphere (given approximately by linear extension of the beginning segment of the diagram shown) by up to few tenths of a degree; the range-correction diagram deviates, from the standard, by 50 feet near $X = 230$ miles, and by 80 feet near 340 miles.

E. Steeply-Rising-and-Then-Level Layer

In Fig. 12 the transmitter is at the bottom of a layer with a single dN/dh vs h peak shown; the layer rises at a 2-degree elevation angle for 750 feet of height and then levels horizontally. (After leveling off, the top of the layer lies along the top of the trapped rays shown.) The shape and the amplitude of the dN/dh peak does not vary with x. The change in N through the layer is 80 N units.

The beginning, rising segment of the layer bends rays away from the hole. This rising segment—which covers only a small height interval, but which is strategically placed and has a properly sloping alignment relative to the trajectories of the rays intercepting the segment—causes the extensive ray-scarce area in agreement with the unusual and wide radio hole observed far within the standard horizon in ground-to-air propagation in Fig. 4. The level segment of the layer traps the rays with initial angles smaller than 1 degree. The resulting duct keeps the rays outside the duct from reaching as far as the standard tangent ray; this checks the fact that in Fig. 4 the radio field intensity dies out exponentially at a range short of the standard horizon.

In Fig. 12 the trapped rays reach as far downward as 1300 feet below the transmitter. If the surface of a bay intervenes at 35 feet below the transmitter (which is the case in Fig. 4), the rays which are shown trapped would all be reflected at the surface, but would still be trapped in a duct (with successive reflections at the surface).

F. Horizontally Varying Layer Measured with Propagation

In Fig. 13 the dN/dh vs h profile shown, consisting of a single dN/dh peak for the layer, is simplified from several N profiles measured during the air-to-air propagation flight in Fig. 5. The height of the layer varies with x in sloping-line sections; this is shown by the diagram H which, to avoid confusion, is displaced 2000 feet upward from the actual height of the layer. The amplitude, P, of the dN/dh peaks is constant from 0 to 210 miles, falls to zero from 210 to 250 miles, and is zero beyond 250 miles. With the transmitter inside the layer at $x = 0$, some rays are trapped in a leaking duct. At

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[14] C. I. Aslakson, "New determinations of the velocity of radio waves," *Trans. Amer. Geophys. Union*, vol. 32, pp. 813–821; December, 1951.

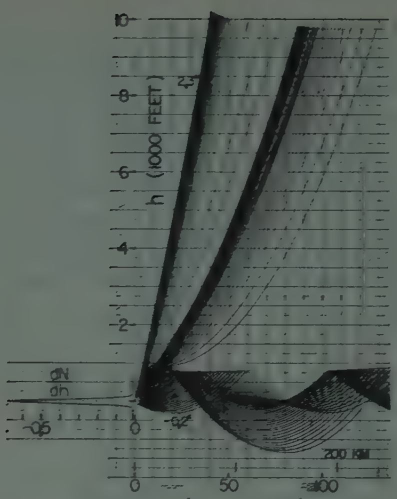

Fig. 12—Pattern with hole which correlates with unusual ground-to-air radio hole in Fig. 4. Transmitter is at bootom of a rising-and-then-level layer.

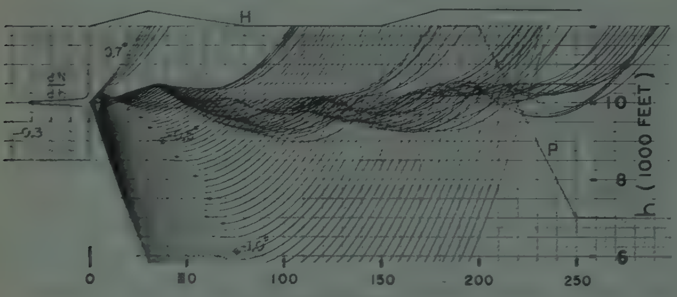

Fig. 13—Pattern with leaking elevated duct; interference between trapped and nontrapped rays explains Fig. 5. Height H and amplitude P of dN/dh peak varies with x.

$h=10{,}000$ feet, the trapped rays have only small densities for distances greater than 165 miles; the nontrapped rays have an essentially standard density from $x=0$ to 224 miles.

In Fig. 13 the transmitter and layer are in fixed relative positions; in Fig. 5 the transmitting and receiving airplanes flew opposite headings at $h=10{,}000$ feet, while the layer varied with time and distance along the propagation path. However, the airplanes were within the layer a part of the time during propagation.

The lower half of Fig. 5 shows that the observed distances between successive signal minima mostly follow the solid curve, which is for interference between direct and reflected signals in the standard atmosphere over spherical earth; deviations from the standard curve occur near the two, cusp-shaped signal minima.

The upper half of Fig. 5 may be explained as follows: From 0 to 80 miles, the signal shows some interference between direct and ground-reflected signals; the transmitting and receiving airplanes were not yet within the layer for ducting to occur. From 80 to 160 miles, the two wide and cusp-shaped signal minima are due to interference of the trapped rays vs the nontrapped rays in Fig. 13. The phase differences between the trapped and the nontrapped rays vary only slowly with distance in the duct; this can be verified with (3), and explains the large separation in range between the two cusp-shaped minima. The closely-spaced signal fluctuations, in the interval from 80 to 160 miles, are due to interference of the trapped and nontrapped direct rays on one hand vs the ground-reflected rays on the other. Beyond 160 miles, the signal is due chiefly to the nontrapped direct rays in Fig. 13, where the tangent ray reaches 224 miles at $h=10{,}000$ feet, in good agreement with the airplane separation at which the signal dies out exponentially in Fig. 5.

G. Intense Thin Layer at Ocean Surface

In Fig. 14 dN/dh varies with h in the first 30 feet above the surface, with intense negative and positive dN/dh peaks of 3 N units per foot; the refractive-index change through each peak is 9 N units. The dN/dh vs h profile shown does not vary with x. In the ray pattern at the left, the transmitter is at $h=23$ feet, and the rays which have initial angles within -0.25 to 0.25 degree are trapped in a thin duct. The rays with initial angles more negative than -0.25 degree strike, and are reflected by, the earth; their up-going trajectories are not trapped. In the right-hand half of the figure, the rays all start at $h=0$; they are shown to start, separately, at different distances merely to avoid confusion. It is clear that any ray which strikes the ocean surface, from a transmitter above the surface, and is thence reflected at an elevation angle under 0.25 degree, would be trapped in a duct; this duct is only 6 feet thick, as shown.

When the signal was observed in Fig. 6, measurements were made also with a refractometer above the ocean surface. The refractivity N, recorded as a function of time at fixed points within 30 feet above the surface, showed large fluctuations of up to 30 N units in time intervals of the order of one second. The N vs h profiles measured above 30 feet, at the same time, were very smooth. With this in mind, and to explain Fig. 6, an assumption is made: 1) there is a thin layer which lies immediately above the ocean surface, which extends for 160 miles, and in which dN/dh is intensely negative everywhere for long time durations. The intense values of dN/dh, and their rapid changes with time and distance, actually observed above this thin layer, are irrelevant in what follows.

The signal within the standard horizon SH in Fig. 6 fluctuates spatially with only small amplitudes; the radiation patterns of the transmitting and receiving antennas are not the cause of this. Thus an assumption is warranted: 2) on reflection by the ocean surface in Fig. 6, the elevation angle of a ray at reflection becomes smaller than its elevation angle at incidence. In this assumption, the angles are measured from the horizontal direction—the x direction, concentric with the spherical earth. The assumption does not preclude the validity

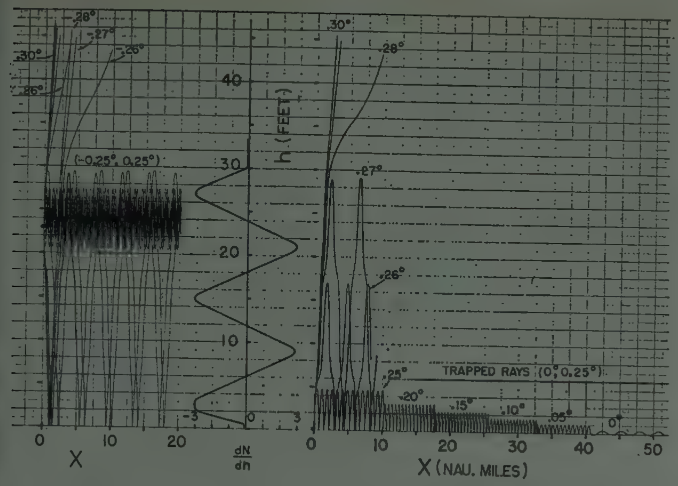

Fig. 14—Patterns each showing trapping of rays by a thin, negative dN/dh peak. Rays escaping from surface duct at right explains Fig. 6.

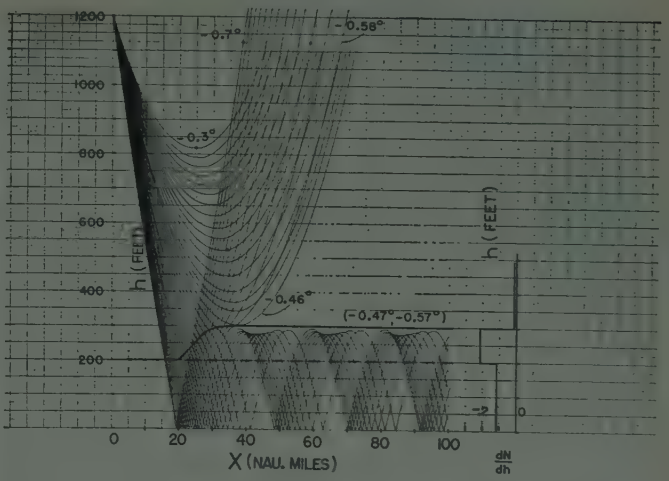

Fig. 15—Pattern showing trapping of rays with transmitter far above duct. Top of layer rises slightly between $x=20$ and 30 miles.

of Fresnel's law, that the angles of incidence and reflection are equal, in reflections by an irregular surface —provided the angles are measured with reference to the locally-tangential planes of that surface. The assumption finds support also in the observed occurrences of radio holes in airborne propagation over water.

With the assumptions 1) and 2), the observed signal extending so far beyond the standard horizon in Fig. 6 can be explained by rays leaking from a duct at the ocean surface. For illustration suppose that, with the transmitter at $h=23$ feet, all the rays with initial angles more negative than -0.07 degree strike the ocean, and that the rays with initial angles between -0.78 and -0.07 degree are reflected at elevation angles between 0.25 and 0.02 degree respectively. Then these rays are all trapped in a duct, only 6 feet thick as in Fig. 14. It can be shown (with ray tracings omitted here) that the rays within initial angles from -0.78 to -0.28 degree can escape from the duct, for example at ranges of between 25 and 65 miles from the transmitter, and then give the strong signal (which is up to and slightly above the inverse-distance field intensity) in the interval from 115 to 160 miles in Fig. 6. The rays with initial angles from -0.28 to -0.27 degree can escape at ranges between 65 and 125 miles, and give the weak signal observed from 160 to 220 miles. The rays with initial angles from -0.27 to -0.07 degree can escape at ranges between 125 and 160 miles, and give the observed strong signal from 220 to more than 265 miles.

H. Layer with Shaped Top at Ocean Surface

In Fig. 15 the thickness of the layer is 200 feet from $x=0$ to 20 miles; it increases to 300 feet between $x=20$ and 30 miles, and remains 300 feet beyond 30 miles. With just this localized and minor shaping in the top of an otherwise usual layer, an unusual effect is obtained: a duct is formed at the ocean surface with the transmitter 900 feet above the layer. The duct consists of rays which become trapped after being reflected at the ocean surface (at $h=0$); these trapped rays lie within an 0.1 degree beamwidth of initial elevation angles at the transmitter. Rays lying within a comparable beamwidth of initial angles can be trapped in a surface duct even with the transmitter much higher than in Fig. 15, provided the conditions of radio-wave reflections at the ocean surface are such that the elevation angle of a ray is smaller at reflection than at incidence (see discussion of Fig. 14). This explains the occasional detections by airborne radars of surface targets at ranges up to hundreds of miles beyond the standard horizon; such detections have been made by radars flying reportedly as high as 15,000 feet.

VII. Remarks

Radio holes far within the standard horizon, antiholes with fluctuating-enhanced signals far beyond the standard horizon, and ducting effects extending to great distances are all possible in both air-to-air and ground-to-air propagation, as the above ray tracings show. However, to account for them, considerations of rather gross and simple features of atmospheric layers suffice in the air-to-air case; localized details of the layers, or strategically deployed variations of the layers with distance, are crucial in the ground-to-air case. Dense-radio fadings are accounted for by horizontally varying layers or smaller refractive index inhomogeneities, both air-to-air and ground-to-air.

The rays from a transmitter, such as in each ray pattern, delineate the domain, in space, of atmospheric refraction—the domain of primary radio-wave illumination and visibility of the transmitter. As the rays often extend far beyond the standard horizon of the transmitter, it is convenient to speak of a "refraction horizon"—a horizon which is determined by the farthest distances reached by appreciable densities of rays from the transmitter, a horizon which depends on prevailing layers in the air and on the transmitter's position relative to the layers. Within this refraction horizon, there may occur large gaps which are not reached by rays from the transmitter.

APPENDIX

Use of Differential Analyzer for Ray Tracing

The ray tracings in Section VI were obtained with either a REAC (Reeves Electronic Analog Computer, Reeves Instrument Company, New York) or a GEDA (Goodyear Electronic Differential Analyzer, Goodyear Company, Ohio). The REAC and GEDA have comparable capabilities; there is a large literature on analog computers such as these.[15] The following is a guide for nonspecialists.

In solving (1) with an analog computer, the independent variable x is represented by a voltage varying linearly with time t in the computation; the dependent variables h, dh/dx, and d^2h/dx^2 are represented by voltages varying nonlinearly with t. Thus, leaving aside scaling (multiplying) factors for simplicity, (1) becomes

$$h'' = \frac{d^2h}{dt^2} = \frac{\partial n}{\partial h} + \frac{1}{a}\,. \tag{5}$$

A given $\partial n/\partial h$ vs h profile constitutes the "input function" in the computation.

To trace a single ray let us assume for the moment, that a voltage representing dn/dh as a function $h(t)$ is available at the input to the integrator I_1 in Fig. 16. Here $h' = dh/dt$, and for the moment we take dn/dh to depend only on h. With a constant voltage $1/a$ in parallel with dn/dh at the input, I_1 integrates the sum $(dn/dh + 1/a)$; the output of I_1, according to (5), is $-h'$. The initial value h_0' of h' for the ray concerned is introduced as a constant voltage h_0' at the "initial condition" terminal of I_1. The output of I_1 is then integrated by the integrator I_2, where the initial value of h for the ray is introduced as a constant voltage h_0. The output of I_2, after passing through potentiometer P and amplifier A, gives a voltage Kh which is proportional to h and varies as function of time in the computation of the ray.

The voltage Kh provides the h-axis variations of the input function generator, in the course of tracing the ray. This generator may consist of a rotating drum (6-inch diameter or larger) which is driven through servomechanisms by Kh. Wrapped around this drum is a graph paper on which a wire curve, representing the dn/dh vs h profile, is glued. A potentiometer PP—perpendicular to the h-axis, and consisting of a knife-edge ridge of plastic (unbreakable) material—makes continuous contact with the wire as the drum rotates. With a proper constant voltage across the potentiometer, the voltage on the wire goes through the variation of dn/dh with h while h is being varied in the course of tracing the ray. Thus the voltage on the wire curve, connected to the input of I_1, fulfills the assumption made above.

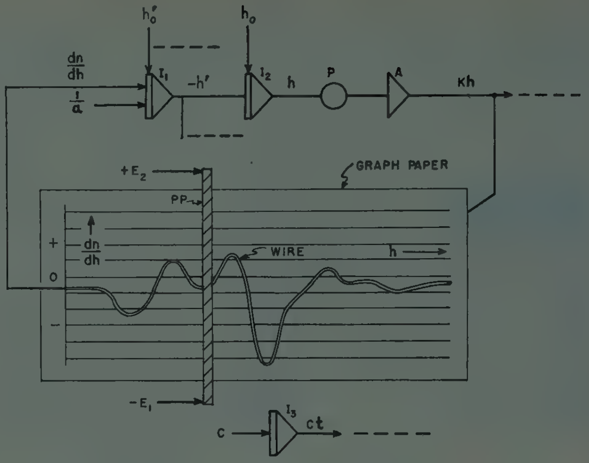

Fig. 16—Schematic diagram of ray tracing with analogue computer. Dashed lines denote voltages taken to output-plotting boards.

In place of the above type of function generator, a diode and relay arrangement can be used for generating a function in sloping-line segments. This latter arrangement has an advantage of fast response. A typical diode-function generating unit has twelve sloping-line segments available, and multiple units can be used in series. With a diode-function generator, it is simple to arrange for the intensity and the center height of each dn/dh vs h peak in a profile to vary with distance x; this is done by use of additional diode-function generators for accommodating the variations of the intensity and the center height with x in sloping-line segments.

The computers (REAC or GEDA) used have rated tolerances of 0.1 per cent in the quality of the computing components. In practice this means that our ray-tracing results are accurate to within a fraction of 1 per cent of the plotted values wherever the rays are reproducible in the time duration of plotting one ray pattern (about half an hour). The rays which graze a layer at nearly zero values of elevation angles are not individually reproducible to within 1 per cent; however, these rays as a group are highly consistent, in the sense that they collectively cover the same area and the same ranges of initial and arrival angles in a given ray pattern, from one trial to the next.

The latest, and most advanced, analog computers manufactured have rated tolerances of 0.01 per cent; the best diode-function generators are capable of generating a reproducible, sharp peak (spike) occurring over a height interval as small as a thousandth of the total height concerned in a dn/dh vs h profile.

ACKNOWLEDGMENT

The writer is greatly indebted to G. B. Fanning and F. P. Miller who led the Wave Propagation Section in WADC; F. T. Sansom, R. T. Harnett, and H. R. McCarter for ray tracing; S. B. White, F. Overcash, and C. Hines for propagation; P. Springer for support.

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[15] C. L. Johnson, "Analog Computer Techniques," McGraw-Hill Book Co., Inc., New York, N. Y.; 1956.

A Cathode Test Utilizing Noise Measurements*

W. DAHLKE† AND F. DLOUHY†

Summary—**The well-known effect of full shot noise of current saturated parts of a cathode and shot-noise suppression under space-charge-limited conditions is shown to be very useful for evaluation of cathode quality. A test equipment and a practical test performance are described. Test results and their comparison to other methods of cathode evaluation demonstrate the high sensitivity of the proposed test. Alterations of the cathode quality by the method itself are very small. The test has been used in the laboratory for activation studies and cathode life tests during the past three years.**

I. INTRODUCTION

SEVERAL methods are available for measuring the electron emissive power of cathodes [1], [3], [4], [8], [11]. In manufacturing, the method of so-called under-heating curves is frequently used during which the emission current is measured as a function of the heater voltage. This often produces only qualitative results.

The method of measuring the saturation current with pulses is well known. This procedure is especially helpful with those tubes which are to be pulse operated during their lives. However, it must be borne in mind that the amplitude of the peak currents is dependent both upon cathode activity and the magnitude of interface layers of the oxide coating. Further, the barium-oxide layer, normally present on the grid wires, is easily decomposed during pulse operation when there is positive grid voltage. The resulting decomposition products can damage the cathode by poisoning.

This undesirable influencing of cathode activity by the measuring procedure does not appear when a diode-emission test [9] is used. At cathode temperatures of approximately 700°K and an anode voltage limited to 5 volts, such diode-current measurements I_d made during the life-time of a single tube of a definite type provide a clear picture of the changes of saturation current with life. Obviously, the temperature or the heater input of the cathode must be controlled very accurately because, as a result of the exponential dependence of the saturation current upon temperature, even small temperature variations cause large variations of the emission current. Unfortunately this diode test is less suitable for a comparison of the emissivity of different tubes, because standardization of heater inputs in different tubes, even of the same type, provides no real uniformity of cathode temperature, especially along the cathode length. Two tubes may show close agreement between 1) their distributions of temperature along the cathode length, at heater voltage of 2.5 volts and 2) emission current. However, at normal $E_f=6.3$ volts operating conditions, entirely different temperature distributions may exist due to different radiation properties and thermal conductivities. Thus, they can have different emission currents at operating temperatures.

Measurement of mutual conductance [3], [11] as a function of heater power produces quite useful data for the evaluation of emissive abilities of different tubes. At high-cathode temperatures, the emission ability of cathodes is so great that the current drain is space-charge limited. Consequently, the mutual conductance is only slightly dependent upon the heater power. At lower temperatures a saturated condition sets in, and the mutual conductance drops quickly. For production evaluation of cathode emission, this G_m method is too cumbersome and time-consuming. A dynamic G_m measuring method using a by-passed cathode resistance with a heater voltage reduced to approximately 4 volts shows that the better the emission ability of the tube under these conditions, the higher the measured G_m.

In contrast to the mutual conductance G_m which is proportional to the space-charge limited area of the cathode, the well-known shot noise [10], [12–14] of the tube depends very strongly on the area of the saturated parts of the cathode, because of the removal of the space-charge reduction of noise. Shot noise therefore represents a most sensitive measure [4] of cathode quality. The practical performance of this noise test, its evaluation for judging cathode quality, its comparison with other already mentioned cathode tests, and several applications will be described and discussed after a theoretical introduction.

II. THEORY

The mean-square shot noise current is

$$\overline{|i_p|^2} = 2eI_p\Gamma^2\cdot\Delta f = 2eI_{\text{eq}}\cdot\Delta f \tag{1}$$

with e the electron charge, I_p the plate current of the tube under test, Δf the bandwidth of the circuit, and I_{eq} the equivalent plate current of a saturated diode delivering the same noise $\overline{|i_p|^2}$ as the test tube. Introducing the well-known expression [14] for the space-charge reduction factor Γ of a triode into (1), we obtain the desired equivalent noise current

$$I_{\text{eq}} = \begin{cases} I_p & \text{saturated region} \\ 1.29\dfrac{E_T G_m}{\sigma} & \text{space-charge-limited region} \\ I_p & \text{exponential region} \end{cases} \tag{2}$$

of the triode under test, where G_m is the mutual conductance of the triode,

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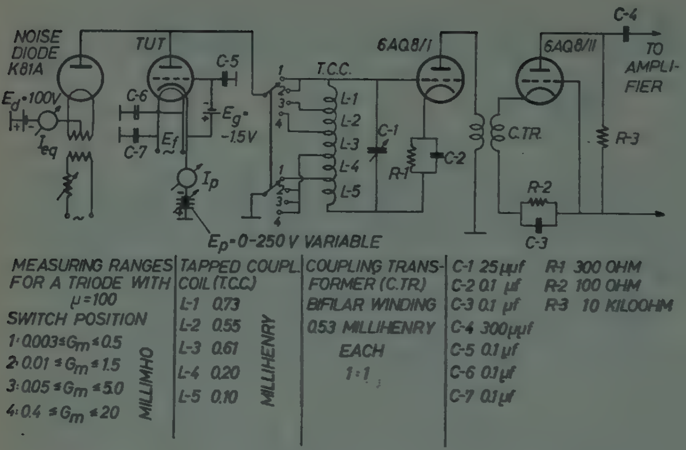

NOISE DIODE K81A
TUT
6AQ8/I
6AQ8/II
C-4
TO AMPLIFIER
E_d=100V
I_{eq}
C-6
C-7
C-5
E_f
E_g=-1.5V
I_p
T.C.C.
L-1
L-2
L-3
L-4
L-5
C-1
R-1
C-2
C.TR.
R-3
R-2
C-3
E_p=0-250 V VARIABLE
MEASURING RANGES FOR A TRIODE WITH μ=100
SWITCH POSITION
1: 0.003 ≤ G_m ≤ 0.5
2: 0.01 ≤ G_m ≤ 1.5
3: 0.05 ≤ G_m ≤ 5.0
4: 0.4 ≤ G_m ≤ 20
MILLIMHO
TAPPED COUPL. COIL (T.C.C.)
L-1 0.73
L-2 0.55
L-3 0.61
L-4 0.20
L-5 0.10
MILLIHENRY
COUPLING TRANSFORMER (C.TR.)
BIFILAR WINDING
0.53 MILLIHENRY EACH
1:1
C-1 25 μμf
C-2 0.1 μf
C-3 0.1 μf
C-4 300 μμf
C-5 0.1 μf
C-6 0.1 μf
C-7 0.1 μf
R-1 300 OHM
R-2 100 OHM
R-3 10 KILOOHM

Fig. 1—Input circuit of the measuring amplifier.

$$\sigma = \frac{1}{1 + \frac{1}{\mu}\left(1 + \frac{4d_{gp}}{3d_{cg}}\right)} \tag{3}$$

is a function of the electrostatic amplification factor μ, and the distances d_{gp} and d_{cg} between grid plate and grid cathode respectively, and

$$E_T = \frac{kT_K}{e} \tag{4}$$

is the so-called temperature voltage of the cathode temperature T_K with k the Boltzmann constant.

III. Test Equipment

The principal circuit for the measurement of shot noise is shown in Fig. 1. The tube under test (TUT) is connected to the input of the preamplifier stage by means of a tapped coupling coil. For noise calibration a noise diode K81A is connected parallel to the input. Its plate voltage $E_d = 100$ volts is kept constant to ensure temperature-limited operation. The dc current I_{eq} of the diode is regulated by adjusting its heater voltage.

To enable a quick change in measuring different tube types, the tube under test is mounted on an exchangeable socket. The tube has its own voltage supply. The grid voltage is kept constant at $E_g = -1.5$ volts to provide a rather uniform current density along the cathode. The plate voltage E_p is variable in order to regulate the dc plate current I_p.

The preamplifier consists of a twin triode 6AQ8 (see Table I) operating in a modified cascode connection [2]. A suitable position of the switch (Fig. 1) is chosen, depending on the test tube's transconductance, to give an optimal noise matching of the first section of the 6AQ8 triode to the test tube. The input admittance of the preamplifier is made large compared to the output conductance of the test tube, so that the input voltage of the preamplifier is directly proportional to the shot-noise current i_p for all plate currents I_p. The second section of the 6AQ8 tube is coupled in a normal grounded grid connection to the first system by means of a transformer with bifilar winding at one to one ratio.

TABLE I

Operating Characteristics

		6AQ8 (ECC 85) Twin Triode	6BX6 (EF 80) Pentode
Heater voltage	E_f	6.3 v	6.3 v
Plate voltage	E_p	250 v	170 v
Screen grid voltage	E_{g2}	—	170 v
Control grid voltage	E_{g1}	−2.3 v	—
Cathode-Bias resistor	r_c	—	160 ohm
Plate current	I_p	10 ma	10 ma
Screen grid current	I_{g2}	—	2.5 ma
Transconductance	G_m	5.9 mmho	7.4 mmho
Amplification factor	μ	57	50

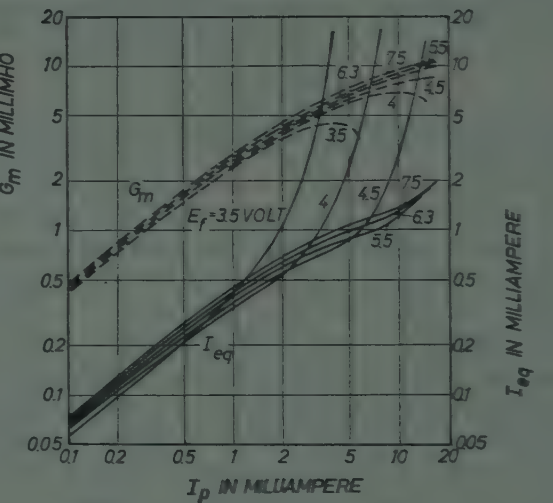


Fig. 2—Transconductance and noise characteristics of a 6BX6 pentode at $E_g = -1.5$ volts. Heater voltage E_f = parameter.

The voltages of the preamplifier (not shown in Fig. 1) are supplied by the following multistage amplifier. It has a center frequency of 470 kc and a bandwidth of 20 kc. Its last stage is connected to a full-wave diode rectifier operating on a load resistor of 10k ohms where a high-resistance voltmeter serves as an output indicator. Under the described conditions of matching, the voltmeter deflection is directly proportional to the shot-noise source i_p and, according to (1), to the square root of the equivalent diode current I_{eq}, which is the desired quantity. For noise calibration, the output voltmeter is simply read as a function of the dc current I_{eq} of the noise diode with zero-plate voltage on the tube under test.

IV. Test Results

In Fig. 2 the measured values of mutual conductance, G_m, and of the diode current I_{eq}, are plotted as a function of the plate current I_p. Eq. (1) relates I_{eq} to the shot-noise current. The results apply to a tube type 6BX6 in triode connection at $E_g = -1.5$ volts. The normal operation conditions of this tube type are given in Table I. Heater voltage E_f is parameter. G_m curves have the usual shape [11], which is affected only slightly by the heater voltage, as long as all elements of the cathode operate space-charge limited. The curves

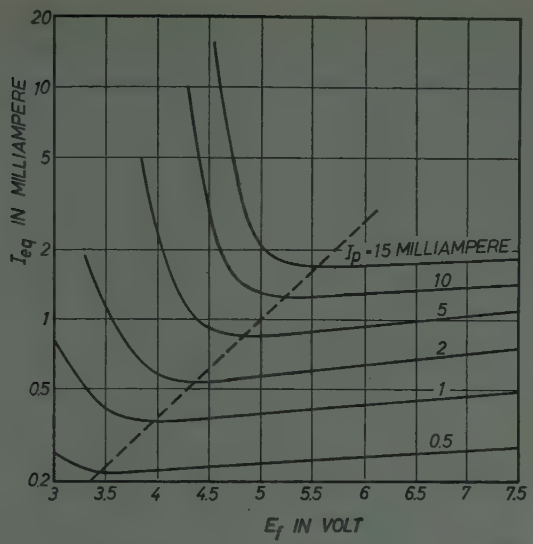


Fig. 3—Noise characteristics of a 6BX6 pentode at $E_g=-1.5$ volts. Plate current I_p=parameter.

shown are similar for plate currents less than 2 ma but depart progressively at higher and higher currents as the heater voltage is raised. The reduction in G_m is produced by the fact that progressively more elements of the cathode become saturated as the plate current is increased or as the heater voltage is reduced so that these elements do not contribute to the mutual conductance.

The curves for I_{eq} run approximately parallel to the G_m curves at low values of plate current. With fixed values of plate current, the curves for noise current as well as the G_m curves for high-heater voltage are only slightly above those for low-heater voltage. With increasing plate current the I_{eq} curves begin to rise very rapidly at first for the low-heater voltages. This influence of the increased effect of saturation of the cathode which shows itself in the noise current at $E_f=3.5$ volts and $I_p=0.5$ ma very markedly as a cross-over point of several noise curves, becomes noticeable in the G_m curve only above $I_p=2$ ma as a barely perceptible decrease.

This behavior may be understood, if we consider that the mutual conductance is determined by all the elements of space-charge-limited emission, while the noise is determined principally by the elements with saturated emission, predominantly due to a weighting factor $1/\Gamma^2 \gg 1$. It must be noticed that the curves for I_{eq}, according to Fig. 2 at high values of plate current at times exceed the saturated shot-noise current prescribed by the limit $I_{eq}=I_p$. van der Ziel [14] kindly suggested to the authors that part of this excess noise and anomalies shown in some of the figures are due to flicker noise and that in order to find the true shot-noise effect, one has to go to frequencies of 5–15 mc.

The noise characteristics of Fig. 2 with the parameter E_f may also be described by other representations. In Fig. 3 the diode current I_{eq} is plotted in logarithmic scale as function of heater voltage E_f. The plate current I_p is the parameter. We see that I_{eq} is a slowly rising function of E_f at high-cathode temperatures. Saturation of I_p occurs at low values E_f accompanied by a strong increase of noise. The resulting noise minimum of the different I_p curves are joined by a dotted straight line. Every point corresponds to the cross-over points already shown in Fig. 2.

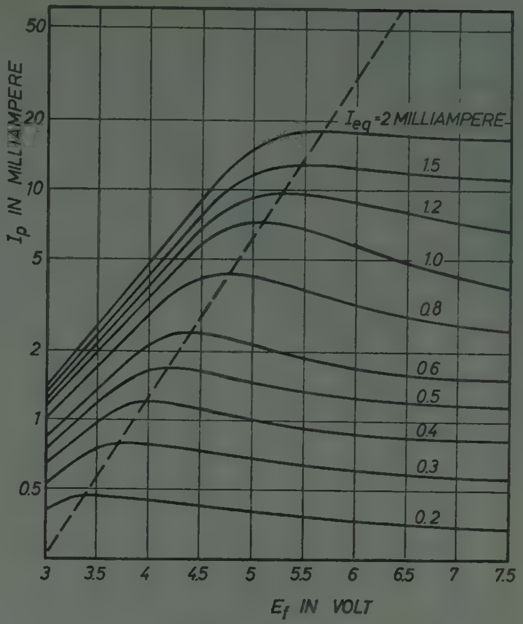


Fig. 4—Noise characteristics of a 6BX6 pentode at $E_g=-1.5$ volts. Equivalent diode current I_{eq}=parameter.

In Fig. 4 the plate current I_p is plotted on a logarithmic scale as function of E_f with I_{eq} as the parameter. I_p increases exponentially with rising E_f at low-heater voltages. Then, corresponding to the cross-overs in Fig. 2, remarkable maxima occur which are joined again by a dotted straight line. Its extrapolation to the normal heater voltage $E_f=6.3$ volts indicates a cross-over current of $I_p=50$ ma. The effect of current saturation at the fixed E_f values of 3.5 and 4 volts visible as maxima of G_m in Fig. 2 can already be detected as maxima of I_p in Fig. 4 at about 1/7 of the corresponding plate current. This relation implies the high sensitivity of the noise test.

V. Comparison of Cathodes

The results given in Section IV above relate to a well-activated cathode of a 6BX6 tube. These shall be compared now with a very poorly activated cathode of the same type. Fig. 5 shows the measured results in the same representation as Fig. 2 which was for the well-activated cathode. The differences between both of the families of characteristics are very remarkable. Comparing first the mutual conductance, the G_m maxima in Fig. 5 for the bad tube are lower by more than one decade than those in Fig. 2. Besides this difference in cathode saturation, the G_m curves of the bad tube show also a considerably higher dependence on E_f than the good one. That means, the effective space-charge-

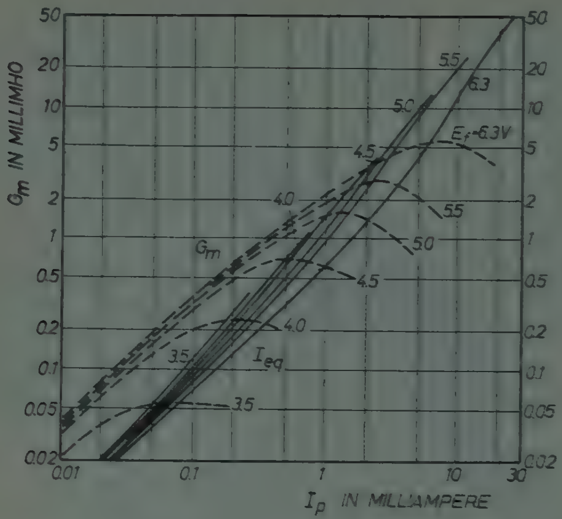


Fig. 5—G_m and noise of a poorly-activated 6BX6 pentode. $E_g=-1.5$ volts E_f=parameter.

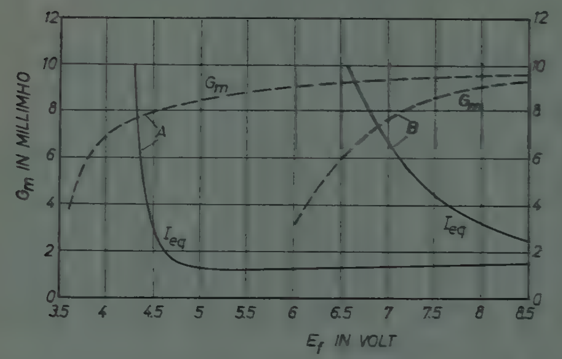


Fig. 6—Comparison of tubes 6BX6. A=well-activated, B=poorly-activated cathode. $E_g=-1.5$ volts, $I_p=10$ ma.

limited area of the cathode is strongly temperature dependent. The cathode has noticeable patches, it is quite nonuniform. These conclusions are confirmed by the noise characteristics. The poor cathode does not show a cross-over point at all. Parts of the cathode are saturated even at very-low-plate currents. and normal heater voltage. The good cathode shows a rapid increase of I_{eq} with I_p when turning from space-charge limitation to saturation, while the poor cathode shows nearly straight lines of about 45 degrees slope for I_{eq} as function of I_p. The cathode is very nonuniform so that saturated patches exist independent of the operating conditions.

Curves A and B of Fig. 6 show the characteristics G_m and I_{eq} as functions of E_f in linear scales for the same well-activated cathode (A) of Fig. 2 and the poorly activated cathode (B) of Fig. 5. During the measurements the plate current $I_p=10$ ma and the grid voltage $E_g=-1.5$ volts were kept constant for the two 6BX6. A strong correlation between G_m and I_{eq} curves is obvious. Decreasing G_m values correspond to rapidly increasing noise I_{eq}. The uniform cathode A shows a comparative sharp knee of I_{eq}, while the nonuniform cathode B has a smooth noise curve. Lowering the heater voltage, all parts of the cathode A become saturated quite uniformly below $E_f=4.5$ volts. The poor cathode B has saturated patches all over the range of E_f.

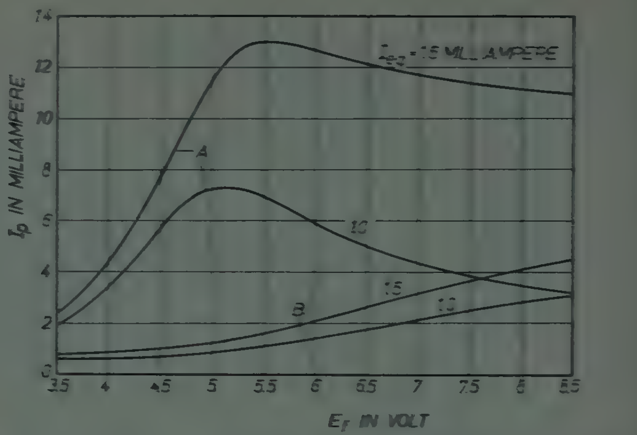
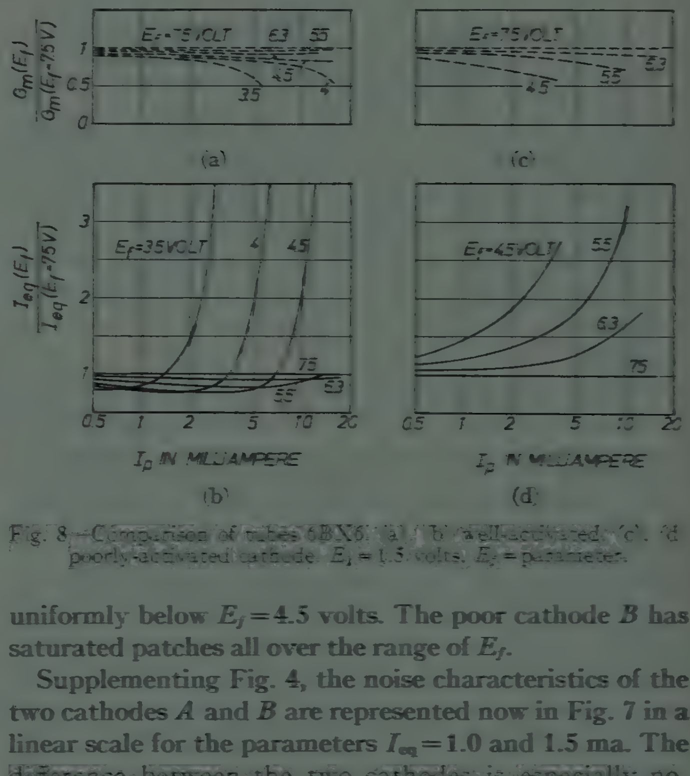


Fig. 7—Comparison of tubes 6BX6. A=well-activated, B=poorly-activated cathode. $E_g=-1.5$ volts, I_{eq}=parameter.



(a) (c)

(b) (d)

Fig. 8—Comparison of tubes 6BX6. (a), (b) well-activated; (c), (d) poorly-activated cathode. $E_g=1.5$ volts. E_f=parameter.

Supplementing Fig. 4, the noise characteristics of the two cathodes A and B are represented now in Fig. 7 in a linear scale for the parameters $I_{eq}=1.0$ and 1.5 ma. The difference between the two cathodes is especially notable at heater voltages below 5 volts.

To get an even more suitable representation for the comparison of cathodes, the results of Fig. 2 were replotted in Fig. 8 in a different form. Figs. 8(a) and 8(b) refer to a tube with a good cathode, Figs. 8(c) and 8(d), to a tube with a poor cathode with nonuniform emission. The upper part of the figure shows the ratio of G_m at the given heater voltage to the G_m at 7.5 volts for a grid voltage $E_g=-1.5$ volts plotted as a function of the plate current I_p. The lower part of the figure gives the noise values of I_{eq}, again referred to the reading at $E_f=7.5$ volts, as a function of plate current I_p. Heater voltage is the parameter.

In the tube with a good cathode (Figs. 8(a) and 8(b)), the noise shows a surprisingly steep rise with increasing current, while the mutual conductance shows a much less pronounced drop which becomes noticeable only at considerably higher plate current. The fairly uniform cathode shows a transfer from the space-charge-limited region to the saturated region at relatively high-plate current. In the tube with a poor cathode (Figs. 8(c) and 8(d) this effect becomes noticeable at the lowest plate currents. This is produced by small areas of saturated emission from the cathode which increase continually with increasing plate current and which, at low values of plate current, reach values shown only at high currents by the good cathode.

VI. Simplified Noise Test

For cathode evaluation in a manufacturing process the measurement of all the noise characteristics I_{eq} according to Fig. 2 or Fig. 8 as function of the plate current I_p is by far too time-consuming. Even the measuring of only one curve I_{eq} corresponding to Fig. 6 as function of heater voltages E_f is too lengthy for production control, although it may deliver valuable laboratory information. For this purpose a simplified noise test has been found useful which will be described below.

The tube under test is always triode connected. The grid-bias voltage $E_g = -1.5$ volts, is chosen to give zero-grid current, the heater voltage is kept constant at a suitable value of about $E_f = 5.0$ volts, as indicated to be desirable by Fig. 7. For testing, the plate voltage E_p of the tube is increased rather quickly and steadily starting from zero up to such a value that the amplifier of the test equipment of Fig. 1 shows a previously selected fixed noise value, *i.e.*, $I_{eq} = 1.5$ ma. Then the corresponding plate current I_{pn} of the test tube is read as a measure of noise and cathode quality.

From Fig. 7 we see that the higher the test value I_{pn}, the better the cathode. For the 6BX6 the readings $I_{pn} \geq 10$ ma correspond to very good cathodes, and $I_{pn} \approx 1$ ma to very poor cathodes.

Besides its simple performance, the noise test I_{pn} has the advantage of running the tubes not too far from their normal grid and heater voltages, so that the above mentioned difficulties of the diode test I_d are avoided. Plate current is drawn only for a few seconds. Its peak value does not much exceed 1 ma for poor cathodes and 10 ma for good ones. Alteration of the cathode quality by the test method itself is therefore extremely small.

To study the correlation between the results of the three tests I_{pn}, G_m, I_d, thirty 6BX6 pentodes were tested according to the conditions of Table II. The results are shown in Fig. 9. In the upper diagram the measured values of G_m for each of the tubes are marked at the corresponding values of the diode current I_d as abscissa. In the lower diagram the data on I_{pn} are presented. The measured points are well-approximated by the so-called least square-trend lines. This proves a strong correlation among all three tests.

TABLE II

Data on Readings for Various Cathode Tests on 6BX6

	I_{pn}—Noise test	G_m—Test	I_d—Diode Test
Fixed values	$E_f = 5$ v $E_{g1} = -1.5$ v $I_{eq} = 1.5$ ma	$E_f = 4$ v $E_p = E_{g2} = 170$ v $r_c = 160$ ohm	$E_f = 2.5$ v $E_p = E_{g1} = E_{g2} = 5$ v
Reading	Plate Current I_{pn} in ma	Mutual conductance in momh	Diode current I_d in ma
Note	Regulate $E_p = E_{g2}$ so that $I_{eq} = 1.5$ ma	Dynamic method	Constant heater power

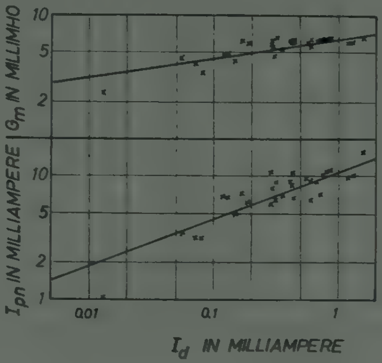


Fig. 9—Correlation of cathode tests. I_{pn}, G_m, I_d (see Table II).

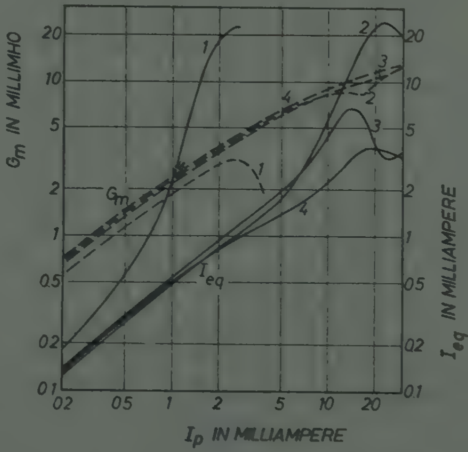


Fig. 10—G_m and noise of 6BX6 in different states of cathode activation.
Curves 1: pumped but nonactivated
Curves 2: after activation
Curves 3: after 120 hours operation (Table I)
Curves 4: after 190 hours operation (Table I)
$E_g = -1.5$ volts; $E_f = 6.3$ volts.

VII. Cathode Activation and Noise

Some applications of noise measurements to the study of cathode activation are possible. Fig. 10 shows the measured mutual conductance G_m and noise characteristics I_{eq} of a 6BX6 in different states of activation as function of the plate current for a constant heater voltage $E_f = 6.3$ volts. Coordinates are the same as in Fig. 2. Curves 1 correspond to the pumped but unactivated state of the cathode, curves 2 to its state at the end of the normal activation processing, curves 3 and 4 to the tube after 120 and 190 hours operation according to conditions shown in Table I. We see from the shape of the characteristics that a progressive increase of saturation current has occurred from curve 1 to 4. The

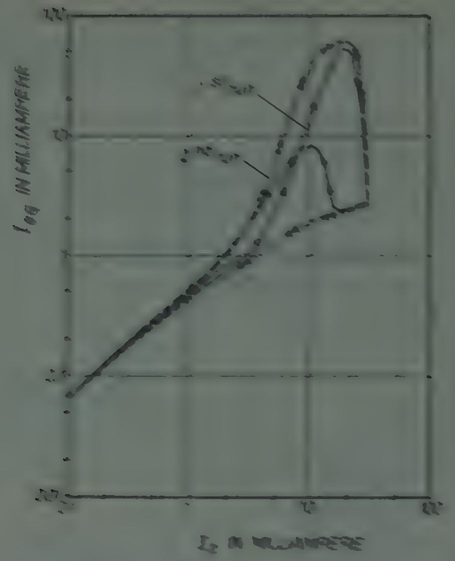


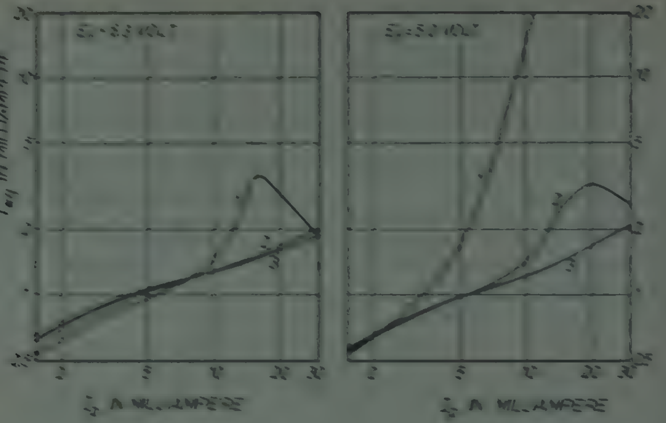
Fig. 11—Hysteresis of noise curves. $E_g=-1.5$ volts; $E_f=6.3$ volts.

activation process is accompanied by a noticeable translation of the G_m lines to higher G_m values. The active and therefore space-charge-limited area of the cathode increases with activation. The noise curves show a corresponding transfer of saturated patches into space-charge limitation. Between $I_p=10$ and 16 ma the G_m curve 2 reveals a typical current saturation which, however, can be overcome by further rising plate current. A similar but smaller cathode saturation is hardly perceptible at G_m curve 3. The small G_m effects are accompanied with large maxima of the noise curves. Such a maximum is even detectable clearly after 190 hours of life from noise curve 4, while such an effect cannot be estimated from the corresponding G_m curve.

The described anomaly of noise shows a hysteresis loop with time as pictured in Fig. 11 for a 6BX6 at $E_f=6.3$ volts. With growing plate current the noise increases from a low value up to $I_{eq}=50$ ma. and then drops rather quickly to $I_{eq}=1$ ma. With falling I_p the noise again reaches its starting value after passing a lowered maximum. The activation state of the cathode has improved after a second run as indicated by the dashed curve. These noise measurements reveal changes in cathode quality that can barely be detected by other and more conventional means.

The method becomes still more sensitive when the heater voltage E_f is lowered as shown in Fig. 12. Fig. 12(a) depicts $E_f=6.3$ volts. Curve 1 corresponds to the activated cathode, curves 2 and 3 to the tube after operating for 130 and 190 hours respectively. Fig. 12(b) at $E_f=5.0$ volts shows details which cannot be perceived in the left one.

Finally, in Fig. 13 an interesting application of the simplified noise test to find optimal activation is shown. There the measured emission curves I_{pm} averaged for groups of 5 tubes 6BX6 are plotted in a double logarithmic scale as a function of activation burning time. The tubes were run with heater voltage only as indicated by the parameter E_f. All the curves have essentially the same shape but differ in height and position of their maxima. Each maximum may be characterized by the corresponding coordinates of time and voltage E_f. The values that give a certain maximum of emissive ability may be called "optimal time" and "optimal heater" voltage respectively. To obtain a high emissivity at fixed cathode temperature, the time of activation should approach but not exceed the corresponding optimal time of activation. Similar results may be observed for tubes operating with plate current during the process of activation. In such cases the optimal time of activation will be somewhat shortened. With this information, tube processing and activation schedules have been improved in several cases of tube production. For instance, the method was very successful for passive cathode nickel where considerably shorter activation times and better life results were obtained.



(a) (b)

Fig. 12—Activation of a 6BX6 pentode measured at (a) $E_f=6.3$ volts. (b) $E_f=5.0$ volts with $E_g=-1.5$ volts.
Curves 1: activated
Curves 2: after 130 hours operation (Table I)
Curves 3: after 190 hours operation (Table I).

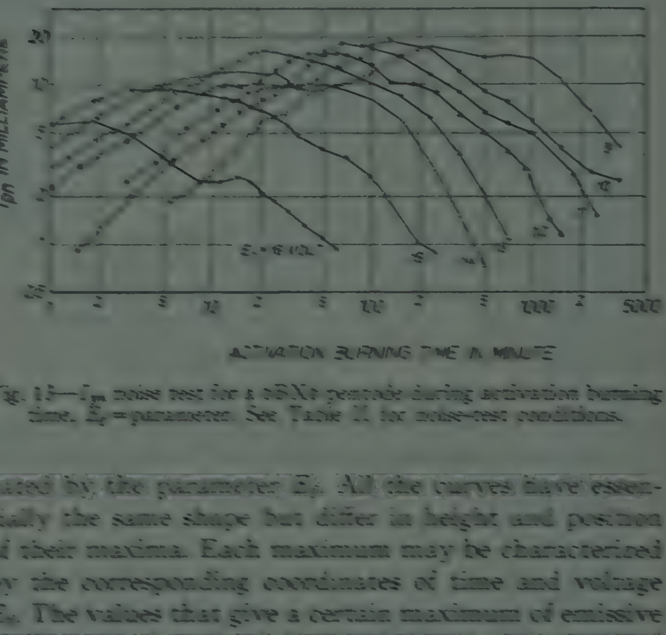


Fig. 13—I_{pm} noise test for a 6BX6 pentode during activation burning time. E_f=parameter. See Table II for noise-test conditions.

ACKNOWLEDGMENT

The authors wish to thank R. Cantz for providing the noise amplifier and M. Bareiss, T. H. Briggs, and W. B. Nottingham, for valuable discussions and help in revising of the manuscript.

BIBLIOGRAPHY

[1] Briggs, T. H. "A Study of Cathode Emission and Measurements" Superior Tube Company, Norristown, Pa. January 16, 1956. (Private Communication.)

[2] Cantz, R. "HF-Amplification with Triodes," *Telefunken-Röhre*, Vol. 30 (February, 1953), pp. 52–69.

[3] Dahlke, W. "Long Life Radio Tubes," *Telefunken-Zeitung*, Vol. 27 (July, 1954), pp. 76–87; *Le Vide*, Vol. 10 (January, 1955), pp. 318–335. "Life Time of Oxide-Cathodes," *Telefunken-Zeitung*, Vol. 30 (March, 1957), pp. 55–61.

[4] Dahlke, W. "Shot Noise of Triodes," *Nachrichtentechn. Fachberichte*, No. 2 (1955), pp. 56–59.
Rothe, H. "Theorie rauschender Vierpole und deren Anwendung," *Telefunken-Röhre*, Vol. 33 (October, 1956), pp. 64–66;

[5] Dow, W. G. *Engineering Electronics*, New York: John Wiley and Sons Co. Inc., 1952, 2nd ed., p. 139.

[6] Nakai, J., Inuishi, Y., and Tsung-Che, Y. "On the Relations between Electron Emission, Conduction and Noise of Oxide-Coated Cathodes," *Journal of the Physical Society of Japan*, Vol. 10 (April, 1955), pp. 437–443.

[7] North, D. O., "Fluctuations in Space-Charge-Limited Currents at Moderate High Frequencies," *RCA Review*, Vol. 4 (April, 1940), p. 463.

[8] Nottingham, W. B. "Thermionic Emission," *Handbuch der Physik*, Vol. 21 (1956), pp. 97–157.

[9] Metson, G. H., Wagener, S., Holmes, M. F., and Child, M. R. "The Life of Oxide Cathodes in Modern Receiving Valves," *Proceedings of the IEE*, Pt. III, Vol. 99 (March, 1952), pp. 69–81.

[10] Rothe, H., und Kleen, W. *Elektronenröhren als Anfangsstufen-Verstärker—2. Auflage*, Leipzig: Akademie Verlagsges, 1953, pp. 291–299.

[11] Rothe, H., und Kleen, W. *Grundlagen und Kennlinien der Elektronen-Röhren—2. Auflage*, Leipzig: Akademie Verlagsges, 1943, pp. 197–199.

[12] Schottky, W. "About Spontaneous Current Fluctuations in Various Conductors," *Annalen der Physik*, Vol. 57 (July, 1918), pp. 541–567.
Schottky, W., and Spenke, E. "About Space Charge Reduction of Shot Noise," *Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern*, Vol. 16 (1937), pp. 1–41.

[13] Thompson, B. J., North, D. O., and Harris, W. A. "Fluctuations in Space-Charge-Limited Currents at Moderate High Frequencies," Part I-V, *Electron Tubes*, Vol. I (March, 1949). Published by *RCA Review*, pp. 58–190. Reprinted from *RCA Review* (January, 1940, *et seq.*)

[14] van der Ziel, A. *Noise*, New York: Prentice-Hall, Inc., 1954, pp. 99–103.

CORRECTION

The definition of VAR as published in "IRE Standards on Radio Aids to Navigation: Definitions of Terms, 1954" (Standard 54 IRE 12. S1), which appeared on pp. 189–209 of the February, 1955 issue of PROCEEDINGS, is in error. It appears in PROCEEDINGS as:

VAR (VHF Aural-Visual Range). A special type of vhf ating at vhf and providing *Radial Lines of Position* in any *Direction* as determined by *Bearing* selection within the receiving equipment. This facility emits a nondirectional "reference" modulation and a rotating pattern which develops a "variable" modulation of the same frequency as the reference modulation. *Lines of Position* are determined by comparison of phase of the variable with that of the reference.

The correct definition is:

VAR (VHF Aural-Visual Range). A special type of VHF range providing a pair of *Radial Lines of Position* which are reciprocal in *Bearing* and are displayed to the pilot on a zero-center, left-right indicator. This facility also provides a pair of reciprocal *Radial Lines of Position* located 90° from the above visually-indicated lines and these are presented to the pilot as aural A-N radio range signals. The A-N aural signals provide a means for differentiating between the two visually-indicated lines (and vice versa).

IRE Standards on Information Theory: Definitions of Terms, 1958*

58 IRE 11. S1

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* Approved by the IRE Standards Committee, June 23, 1958. Reprints of this standard, 58 IRE 11. S1, may be purchased while available from the Institute of Radio Engineers, 1 East 79th Street, New York, N. Y. at $0.50 per copy. A 20 per cent discount will be allowed for 100 or more copies mailed to one address.

INTRODUCTION

Information Theory, in the narrowest sense, is used to describe a body of work, largely about communication problems but not entirely about *electrical* communication, in which the information measures defined below (see *Information Content, Transinformation*) are central. This work is also known, particularly in Europe, as "the mathematical theory of communication." In a broader sense it is taken to include all statistical aspects of communication problems, including the theory of noise, statistical decision theory as applied to detection problems, and so forth. This broader field is sometimes called "statistical communication theory." In a still broader sense its use includes theories of measurement and observation which use other measures of information, or none at all, and indeed work on any problem in which information, in one of its colloquial senses, is important. The first and narrowest sense is the one to which the following definitions apply.

The original information measures defined in information theory were the averaged quantities *Average Information Content* (entropy) and *Average Transinformation* (transmitted information) (*e.g.*, Shannon[1]). The unaveraged quantities *Information Content* and *Transinformation* (information transfer) were introduced later (*e.g.*, Woodward[2]). The use of the unaveraged quantities has since spread. It has caused some controversy, since two basic theorems which justify the definitions of the averaged quantities do not apply in the unaveraged case. However, recent work in coding theory has given added significance to the unaveraged quantities (*e.g.*, Shannon[3]).

The definitions of *Information Content, Transinformation, Equivocation, Redundancy, Message* and other terms whose definitions depend on these apply to the case of a communication system in which transmitted and received symbols are selected from a finite set. Only some of the defined concepts can be extended to other cases, and revision of the definition may be required before doing so. In particular, in the finite case either *Information Content* or *Transinformation* may be taken as basic, and the other as derived. However, *Information Content* does not extend conveniently to other cases, such as selection from a continuous set of possible values, while *Transinformation* can be so extended.

DEFINITIONS

Average Information Content (per symbol) (information rate from a source, per symbol). The average of the *Information Content Per Symbol* emitted from a source.

Note: The terms *Entropy* and *Negentropy* are sometimes used to designate *Average Information Content.*

Average Transinformation (of output symbols and input symbols). *Transinformation* averaged over the ensemble of pairs of transmitted and received symbols.

Binary Code. Any *Code* employing two distinguishable types of *Code Elements.*

Bit (information theory). A unit of *Information Content* equal to the *Information Content* of a *Message* the *a priori* probability of which is one-half.

Note: If, in the definition of *Information Content*, the logarithm is taken to the base two, the result will be expressed in *bits.*

Channel. A combination of transmission media and equipment capable of receiving *Signals* at one point and delivering related *Signals* at another point.

Channel Capacity. The maximum possible *Information Rate* through a *Channel* subject to the constraints of that *Channel.*

Note: Channel Capacity may be either per second or per symbol.

Channel Utilization Index. The ratio of the *Information Rate* (*per second*) through a *Channel* to the *Channel Capacity* (*per second*).

Code. A set of transformation rules to be applied to *Messages* or *Signals.*

Note: Code is sometimes used in a colloquial sense to denote the set of *Code Characters* used by a *Code.*

Code Character. The representation of a discrete value or symbol in accordance with a *Code.*

Code Element. One of a finite set of parts of which the characters in a given *Code* may be composed.

Conditional Information Content (of a first symbol given a second symbol). The negative of the logarithm of the conditional probability of the first symbol, given the second symbol.

Note 1: The choice of logarithmic base determines the unit of *Information Content.* See *Bit* and *Hartley.*

Note 2: The *Conditional Information Content* of an input symbol given an output symbol, averaged over all input-output pairs, is the *Equivocation.*

Note 3: The *Conditional Information Content* of output symbols relative to input symbols, averaged over all input-output pairs, has been called spread, prevarication, irrelevance, etc.

Content, Average Information. See *Average Information Content.*

Content, Conditional Information. See *Conditional Information Content.*

Entropy. See *Average Information Content.*

Equivocation. The *Conditional Information Content* of an input symbol given an output symbol, averaged over all input-output pairs.

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[1] C. E. Shannon and W. Weaver, "The Mathematical Theory of Communication," University of Illinois Press, Urbana, Ill.; 1949.

[2] P. M. Woodward, "Probability and Information Theory, with Applications to Radar," McGraw-Hill Book Co., Inc., New York, N. Y.; 1953.

[3] C. E. Shannon, "Certain results in coding theory for noise channels," *Information and Control*, vol. 1, pp. 6–25; 1957.

Hartley. A unit of *Information Content* equal to the *Information Content* of a message, the *a priori* probability of which is one-tenth.

> *Note:* If, in the definition of *Information Content*, the logarithm is taken to the base ten, the result will be expressed in *Hartleys*.

Information Content (of a message or a symbol from a source). The negative of the logarithm of the probability that this particular *Message* or symbol will be emitted from the source.

> *Note 1:* The choice of logarithmic base determines the unit of *Information Content*. See *Bit* and *Hartley*.
>
> *Note:* The probability of a given *Message* or symbol being emitted may depend on one or more preceding *Messages* or symbols.
>
> *Note 3:* The quantity has been called *Self-Information*.

Information Rate (from a source, per symbol). See *Average Information Content*.

Information Rate (from a source, per second). The product of the *Average Information Content per Symbol* and the average number of symbols per second.

Information Rate (through a channel, per symbol). See *Average Transinformation*.

Information Rate (through a channel, per second). The product of the *Average Transinformation per Symbol* and the average number of symbols per second.

Message. (a) An ordered selection from an agreed set of symbols, intended to communicate information. (b) The original modulating wave in a communication system.

> *Note:* Definition (a) is the sense in which the term is used in communication theory; definition (b) is the sense in which the term is often used in engineering practice.

Message Source. That part of a communication system where *Messages* are assumed to originate.

Mutual Information. See *Transinformation*.

***N*-ary Code.** A *Code* employing N distinguishable types of *Code Elements*.

Negentropy. See *Average Information Content*.

Redundancy (of a source). The amount by which the logarithm of the number of symbols available at the source exceeds the *Average Information Content per Symbol* of the source.

> *Note:* The term *Redundancy* has been used loosely in other senses. For example, a source whose output is normally transmitted over a given channel has been called redundant, if the *channel utilization index* is less than unity.

Relative Redundancy (of a source). The ratio of the *Redundancy* of the source to the logarithm of the number of symbols available at the source.

Self Information. See *Information Content*.

Signal. The physical embodiment of a *Message*.

Ternary Code. A *Code* employing three distinguishable types of *Code Elements*.

Transferred Information. See *Transinformation*.

Transinformation (of an output symbol about an input symbol). The difference between the *Information Content* of the input symbol and the *Conditional Information Content* of the input symbol given the output symbol.

> *Note 1:* If x_i is an input symbol and y_j is an output symbol, the *Transinformation* is equal to

$$[-\log p(x_i)] - [-\log p(x_i \mid y_j)] = \log \frac{p(x_i \mid y_j)}{p(x_i)} = \log \frac{p(x_i, y_j)}{p(x_i)\, p(y_j)}$$

> where $p(x_i \mid y_j)$ is the conditional probability that x_i was transmitted when y_j is received, and $p(x_i, y_j)$ is the joint probability of x_i and y_j.
>
> *Note 2:* This quantity has been called *Transferred Information*, *Transmitted Information* and *Mutual Information*.

Transmitted Information. See *Transinformation*.

Correspondence

Optimum Finite Code Groups*

A problem which has attracted considerable interest recently is that of determining so called "perfect words" or "optimum finite code groups." These are sequences of numbers, X_i, which satisfy the condition

$$\sum_{i=0}^{N-1-k} X_i X_{i+k} = \rho_k = \begin{cases} 0, \pm 1 & k=1, 2, \cdots, N-1 \\ N & k=0 \end{cases}$$

$$X_i = \pm 1.$$

The only known solutions to date are for sequences of length $N=1, 2, 3, 4, 5, 7, 11, 13$. It is also known that solutions of odd length (N odd) satisfy the symmetry condition

$$X_i = X_{N-i}(-1)^{i+(N-1)/2} \quad (N \text{ odd}). \quad (1)$$

Recently, we have found another necessary condition which must be possessed by sequences of odd length. In particular, if

$$X_i = \psi_i X_{i-1}; \text{ then } \psi_{2i} = \psi_i; \quad (N \text{ odd}). \quad (2)$$

Consistency between (1) and (2) imposes very severe restrictions on the existence of solutions. It then can readily be shown that no solutions of odd length exist between $N=13$ and $N=101$. Moreover, there are strong indications that there are very few, if any, solutions of odd lengths larger than $N=13$. We hope to submit a paper covering this material shortly.

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* Received by the IRE, April 3, 1958.

WWV Standard Frequency Transmissions*

Since October 9, 1957, the National Bureau of Standards radio stations WWV and WWVH have been maintained as constant as possible with respect to atomic frequency standards maintained and operated by the Boulder Laboratories, National Bureau of Standards. On October 9, 1957, the USA Frequency Standard was 1.4 parts in 10^9 high with respect to the frequency derived from the UT 2 second (provisional value) as determined by the U. S. Naval Observatory. The atomic frequency standards remain constant and are known to be constant to 1 part in 10^9 or better. The broadcast frequency can be further corrected with respect to the USA Frequency Standard as indicated in the table presented here. This correction is *not* with respect to the current value of frequency based on UT 2. A minus sign indicates that the broadcast frequency was low.

WWV FREQUENCY†

June, 1958 1500 UT	Parts in 10^9
1	−3.4
2	−3.3
3	−3.3
4	−3.3‡
5	−3.2
6	−3.2
7	−3.1
8	−3.0‡
9	−3.0
10	−2.9
11	−2.9
12	−2.9‡
13	−2.9
14	−3.0
15	−3.1
16	−3.2
17	−3.3
18	−3.2
19	−3.2
20	−3.1
21	−3.2
22	−3.3‡
23	−3.3
24	−3.3
25	−3.3
26	−3.4
27	−3.4
28	−3.4
29	−3.4
30	−3.3

† WWVH frequency is synchronized with that of WWV.

‡ Decrease in frequency of 0.5×10^{-9} at 1900 UT at WWV.

The WWV and WWVH time signals are synchronized; however, they may gradually depart from UT 2 (mean solar time corrected for polar variation and annual fluctuation in the rotation of the earth). Corrections are determined and published by the U. S. Naval Observatory.

WWV and WWVH time signals are maintained in close agreement with UT 2 by making step adjustments in time of precisely plus or minus twenty milliseconds on Wednesdays at 1900 UT when necessary; one step adjustment was made at WWV and WWVH on June 11, 1958.

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* Received by the IRE, July 14, 1958.

Storage Capacity in Meteor-Burst Communication Systems*

Campbell[1] has derived a differential equation, the solution of which allowed the specification of the storage capacity of a meteor-burst communication system in terms of the desired probability of filling the store. In a completely independent investigation the same differential equation was derived using a different method. This method also allowed the inclusion of other factors that occur in the communication problem. It should be noticed that with $K=0$, (10) is the same as (34) given by Dr. Campbell.

TRANSMITTER STORE-SIZE DETERMINATION

In this approach the first K bits transmitted are used for synchronizing. Let

$P(x)$ = probability that the information in store prior to a burst be x bits or less
$Q(x)$ = probability that the information in store after a burst be x bits or less
a = arrival rate
t = mean time between bursts
s = decreasing rate (transmitted rate − arrival rate) = $(n-a)$
L = mean time of burst duration
K = number of bits required for synchronization.

$$P(x) = \int_{z=0}^{z=x} e^{-z/at} \frac{1}{at} Q(x-z) dz \quad (1)$$

$$Q(x) = \int_{r=K}^{r=\infty} e^{-r/sL} \frac{1}{sL} P(x+r-K) dr + \int_{r=0}^{K} e^{-r/sL} \frac{1}{sL} P(x) dr. \quad (2)$$

From (2)

$$Q(x) = \int_{r=K}^{\infty} e^{-r/sL} \frac{1}{sL} P(x+r-K) dr + [1 - e^{-K/sL}] P(x). \quad (3)$$

In (1) let

$$y = x - z$$

$$P(x) = \int_{y=0}^{\infty} e^{-[(x-y)/at]} \frac{1}{at} Q(y) dy. \quad (4)$$

In (3) let

$$y = x + r - K$$

$$Q(x) = \int_{y=x}^{\infty} e^{-[(y-x+K)/sL]} \frac{1}{sL} R(y) dy + [1 - e^{-K/sL}] P(x). \quad (5)$$

Differentiating (4) and (5) with respect to x

$$\frac{dP(x)}{dx} = \frac{1}{at} Q(x) - \frac{1}{at} P(x)$$

$$\frac{dQ(x)}{dx} = -\frac{1}{sL} P(x) + \frac{1}{sL} Q(x) \quad (6)$$

$$+ [1 - e^{-K/sL}] \frac{dP(x)}{dx}. \quad (7)$$

From (6)

$$Q(x) = at \frac{dP(x)}{dx} + P(x).$$

---

* Received by the IRE, March 27, 1958.

[1] L. L. Campbell, "Storage capacity in burst-type communication systems," PROC. IRE, vol. 45, pp. 1661–1666; December, 1957.

Substitute into (7)

$$at\frac{d^2P(x)}{dx^2}+\frac{dP(x)}{dx}=-\frac{1}{sL}P(x)+\frac{1}{sL}at\frac{dP(x)}{dx}+\frac{1}{sL}P(x)+\left[1-e^{-K/sL}\right]\frac{dP(x)}{dx}\cdot \quad (8)$$

Collecting terms

$$at\frac{d^2P(x)}{dx^2}+\left[e^{-K/sL}-\frac{at}{sL}\right]\frac{dP(x)}{dx}\doteq 0 \quad (9)$$

or

$$\frac{d^2P(x)}{dx^2}+\left[\frac{e^{-K/sL}(sL)-at}{(sL)(at)}\right]\frac{dP(x)}{dx}\doteq 0. \quad (10)$$

Solving for $P(x)$

$$P(x)=1-\exp-\left[\frac{e^{-K/sL}(sL)-at}{(sL)(at)}\right]x. \quad (11)$$

Thus

$$Pr(n>x)=\exp-\left[\frac{e^{-K/sL}(sL)-at}{(sL)(at)}\right]x. \quad (12)$$

Also let

$$m=\frac{sL}{at}\cdot \quad (13)$$

Then (12) becomes

$$Pr(n>x)=\exp-\left[\frac{e^{-K/mat}(mat)-at}{(mat)at}\right]x \quad (14)$$

or

$$Pr(n>x)=\exp-\left[\frac{e^{-K/mat}m-1}{m}\right]\frac{x}{at}\cdot \quad (15)$$

With h = transmitted rate from (13)

$$m=\frac{sL}{at}=\frac{(h-a)}{a}\,\frac{L}{t}\cdot \quad (16)$$

In (16) L/t is the ratio of the mean time for the duration of a burst to the mean time for the period between bursts. Also, h/a is the ratio of the outgoing bit rate to the incoming bit rate, or stated in another way, the speed change effected by the transmitter. Let

$$D=\frac{L}{t},$$

$$R=\frac{h}{a},$$

then with the proper substitutions

$$m=(R-1)D. \quad (17)$$

RECEIVER STORE-SIZE DETERMINATION

Let

$L(x)$ = probability that the number of bits in store is x or less just before receipt of a transmission burst

$M(x)$ = probability that the number of bits in store is x or less just after the receipt of a transmission burst

f = final service-bit rate

m, k, t, s, L, a are the same as before.

$$L(x)=\int_0^\infty \frac{1}{ft}e^{-r/ft}M(x+r)dr, \quad (18)$$

$$M(x)=\int_0^\infty \left\{[1-P(u)]e^{-u/sL}\frac{du}{sL}+\frac{\partial P(u)}{\partial u}due^{-u/sL}\right\}L(x-u). \quad (19)$$

Substituting

$$P(u)=1-\exp-\left[\frac{e^{-K/sL}(sL)-at}{(sL)(at)}\right]u,$$

(19) becomes

$$M(x)=\int_0^x L(x-u)\frac{e^{-K/sL}}{at}\exp-\left[\frac{ue^{-K/sL}}{at}\right]du. \quad (20)$$

Eqs. (18) and (20) are identical in form to (1) and (2) and because the boundary conditions are the same, the result is of the same form or

$$M(x)=1-\exp-\left[\frac{e^{-K/sL}(ft)-at}{e^{-K/sL}(ft)(at)}\right]x. \quad (21)$$

Therefore,

$$M(n>x)=\exp-\left[\frac{e^{-K/sL}(ft)-at}{e^{-K/sL}(ft)(at)}\right]x \quad (22)$$

is the probability that store-size x in the receiver will not be exceeded.

Or, if it is desired, a ratio of the maximum average speed of the output device to the maximum average speed of the input device $f/a=E$ may be used and (22) becomes

$$M(n>x)=\exp-\left[\frac{e^{-K/sL}E-1}{e^{-K/sL}E}\right]\frac{x}{at}\cdot \quad (23)$$

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Radio Engineering Use of the Cayley-Klein Model of Three-Dimensional Hyperbolic Space*

The purpose of this note is to indicate how the Cayley-Klein model of three-dimensional hyperbolic space can be used in radio engineering.

The Smith chart is a useful tool for dealing with reflection coefficient transformations through bilateral two-port networks. The chart is aptly suitable for performing lossless transformations, because the rim of the Smith chart (the unit circle) is "invariant," being transformed into itself. For lossy transformations, however, the chart is not as suitable, because the unit circle does not remain invariant, being transformed into a circle inside the Smith chart. From a geometrical point of view, a lossless transformation can be performed by using real angles and real distances, whereas a lossy transformation actually requires "complex angles" (or "complex distances"). Since it has been shown (Schilling[1,2]) that a geometric representation of a complex angle (distance) requires three dimensions, we may therefore state that the Smith chart is not the natural tool for treating lossy transformations. To find such a tool we have to look for a surface that is imbedded in three dimensions and transformed into itself (invariant) under the transformation—a "three-dimensional Smith chart."

Reflection coefficient transformations through bilateral two-port networks are performed analytically by the linear fractional transformation

$$\Gamma'=\frac{A\Gamma+B}{C\Gamma+D},\quad AD-BC=1. \quad (1)$$

For lossless two-port networks $B=C^*$, $D=A^*$, the asterisk indicating a conjugate complex quantity. Eq. (1) can be written in the canonic form

$$\frac{\Gamma'-\Gamma_{f1}}{\Gamma'-\Gamma_{f2}}=q\frac{\Gamma-\Gamma_{f1}}{\Gamma-\Gamma_{f2}},\ q=e^{2\mu}=e^{2(\mu'+j\mu'')}, \quad (2)$$

where Γ_{f1} and Γ_{f2} are the fixed points obtained by putting $\Gamma'=\Gamma$ in (1) and q is the multiplier.

Eqs. (1) and (2) can be graphically performed by the use of an elementary inversion method called the isometric circle method.[3,4] For lossless two-port networks the isometric circle method consists in two inversions. The isometric circles are orthogonal to the unit circle of the Smith chart. If the Smith chart is converted into the Cayley-Klein model of two-dimensional hyperbolic space,[5-7] these circles are transformed into straight lines, and the two inversions are converted into two non-Euclidean reflections.[8]

For lossy two-port networks the isometric circle method basically consists in four inversions in the Γ plane. A stereographic mapping of the Γ plane on the surface of the Riemann unit sphere, which is assumed to be the absolute surface of a Cayley-Klein model of three-dimensional hyperbolic space,[9,10] converts the four inversions in the Γ plane into two non-Euclidean reflections in two straight lines in space, for example, L_{12} and L_{13}, both non-Euclidean perpendiculars to an "inner

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* Received by the IRE, March 31, 1958.

[1] F. Schilling, "Über die geometrische Bedeutung der Formeln der sphärischen Trigonometrie im Falle complexer Argumente," *Math. Ann.*, vol. 39, pp. 598–600; 1891.

[2] ——, "Beträge zur geometrischen Theorie der Schwarz'schen S-Funktion," *Math. Ann.*, vol. 44, pp. 161–260; 1894.

[3] E. F. Bolinder, "Impedance and polarization-ratio transformations by a graphical method using the isometric circles," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-4, pp. 176–180; July, 1956.

[4] E. F. Bolinder, "Noisy and noise-free two-port networks treated by the isometric circle method," PROC. IRE, vol. 45, pp. 1412–1413; October, 1957.

[5] J. Van Slooten, "Meetkundige Beschouwingen in Verband met de Theorie der Electrische Vierpolen," W. D. Meinema, Delft, The Netherlands; 1946.

[6] G. A. Deschamps, "Geometrical representation of the polarization of a plane electromagnetic wave," PROC. IRE, vol. 39, pp. 540–544; May, 1951.

[7] E. F. Bolinder, "A survey of the use of non-Euclidean geometry in electrical engineering," *J. Franklin Inst.*, vol. 265, pp. 169–186; March, 1958.

[8] E. F. Bolinder, "Graphical methods for transforming impedances through lossless networks by the Cayley-Klein diagram," *Acta Pol., Elec. Eng. Series*, vol. 7, no. 202; 1956.

[9] F. Klein, "Vorlesungen über Nicht-Euklidische Geometrie," für den Druck neu bearbeitet von W. Rosemann, Springer Verlag, Berlin, Germany; 1928.

[10] F. Schilling, "Die Bewegungstheorie im Nicht-Euklidischen hyperbolischen Raum," vols. I, II, Leibniz-Verlag, Munich, Germany; 1948.

axis” L_1 through two points P_{f1} and P_{f2} on the surface of the unit sphere.[11] The points P_{f1} and P_{f2} are images of the fixed points Γ_{f1} and Γ_{f2} in the Γ plane. The lossy two-port network can thus be represented by the geometric configuration shown in Fig. 1. In this figure the non-Euclidean distance between L_{12} and L_{13} on L_1 is μ', and the non-Euclidean angle between planes through L_{12} and L_1, and L_{13} and L_1, is μ''. The quantity $\mu'+j\mu''$ forms a “complex distance” in Schilling's sense.[1,2]

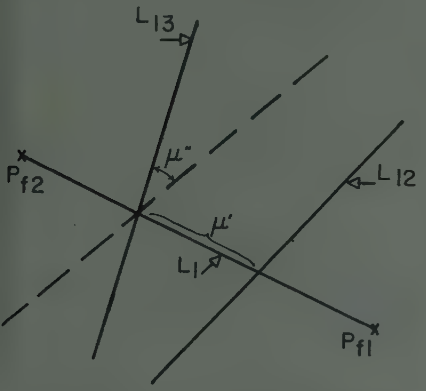

Fig. 1—Geometric configuration representing a bilateral lossy two-port network.

Van Slooten[5] has remarked that just as the Cayley-Klein model of two-dimensional hyperbolic space is suitable for impedance transformations through bilateral lossless two-port networks, so ought the Cayley-Klein model of three-dimensional hyperbolic space be applicable for impedance transformations through lossy two-port networks. Although Van Slooten seems to be of the opinion that the Cayley-Klein model of three-dimensional hyperbolic space is too complicated to be of any use in electrical engineering, the model has nevertheless found many practical applications.

The geometric configuration shown in Fig. 1 can be used in studying problems dealing with bilateral two-port networks. It has been shown how the Klein generalization of the well-known Pascal theorem to three dimensions can be used to analyze such a network from three arbitrary impedance or reflection coefficient measurements.[11–13] The cascading of bilateral two-port networks can be studied by means of the Schilling generalization of the Hamilton theorem, a well-known theorem in spherical trigonometry. The inner axes and their perpendiculars that represent the constituent networks, together with those that represent the resultant network, form a geometric configuration consisting in six lines, all consecutively non-Euclidean perpendiculars to each other (“the Schilling figure”).[11–13] The Cayley-Klein model of three-dimensional hyperbolic space has also been used in studying the efficiency of two-port networks.[14]

The Cayley-Klein model of three-dimensional hyperbolic space has been treated by Deschamps in a basic paper[15] and has recently begun to be applied by de Buhr.[16]

Lastly, let me briefly point out the relation between the Cayley-Klein model and the Poincaré model of the three-dimensional hyperbolic space.

By the “Darboux transformation,” each pair of points inverse in relation to the unit sphere is transformed into the pole of its symmetry plane. This transformation converts the Cayley-Klein model of three-dimensional hyperbolic space into the conformal Poincaré model of three-dimensional hyperbolic space, in which a straight line is represented by an arc of a circle that orthogonally cuts the absolute surface (here the surface of the unit sphere).[7]

From an engineering point of view the Poincaré model of three-dimensional hyperbolic space is rather impractical whereas the Cayley-Klein model of three-dimensional hyperbolic space can be used constructively in studying many important network problems, only a few of which have been outlined in this note.

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[11] E. F. Bolinder, “Impedance Transformations in the Three-Dimensional Hyperbolic Space,” Res. Lab. of Electronics, M.I.T., Cambridge, Mass., Quart. Prog. Rep., pp. 125–128; April 15, 1956.

[12] E. F. Bolinder, “Impedance transformations by xtension of the isometric circle method to the three-imensional hyperbolic space,” *J. Math. Phys.*, vol. 6, pp. 49–61; April, 1957.

[13] E. F. Bolinder, “General method of analyzing bilateral, two-port networks from three arbitrary impedance measurements,” *Ericsson Technics*, vol. 14, pp. 3–35; 1958.

[14] E. F. Bolinder, “Graphical method for determining the efficiency of two-port networks,” Proc. IRE, vol. 45, p. 361; March, 1957.

[15] G. A. Deschamps, “Geometric viewpoints in the representation of waveguides and waveguide junctions,” *Proc. Symposium on Modern Network Synthesis*, Polytechnic Inst. of Brooklyn, N. Y., pp. 277–295; April, 1952.

[16] J. de Buhr, “Die geometrische Darstellungsweise hintereinandergeschalteter, allgemeiner, verlustbehafteter Vierpole,” *AEÜ*, vol. 11, pp. 173–176; April, 1957.

Properties of Root Loci*

The roots of the polynomial $P(s)+KZ(s)$ determine part of the transient behavior of certain types of linear feedback systems. As the constant K varies $(0, \infty)$, the roots trace out loci starting at the roots of $P(s)$ and ending at the roots of $Z(s)$. The roots of $P(s)$ are called poles, whereas the roots of $Z(s)$ are called zeros.

The tangent vector of the loci is

$$u = -\frac{Z(s)}{P'(s)+KZ'(s)}.$$

For the constant K equal to zero the tangent vector indicates the rate of departure from the poles and the angle of departure. Both these quantities are conveniently calculated from the pole-zero pattern of complex s plane. The initial tangent vector at the pole s_{pj} is given by the expression

$$u(s_{pj})_{K=0} = -\frac{\sum_{i=1}^{z}(s_{pj}-s_{zi})}{\prod_{i=1,\, i\neq j}^{p}(s_{pj}-s_{pi})},$$

where

$$P(s) = \prod_{i=1}^{p}(s-s_{pi}),$$

$$Z(s) = \prod_{i=1}^{z}(s-s_{zi}).$$

The magnitude of the vector is the residue of the pole and is calculated by finding the ratio of the zero-to-pole vectors to the pole-to-pole vectors. The angle is given by the well-known formula

$$\phi = 180^\circ + \sum_{i=1}^{z}\phi_{z_i} - \sum_{i=1,\, i\neq j}^{p}\phi_{p_i}$$

where ϕ is the angle of the zero-to-pole vectors and the pole-to-pole vectors.

Substitution of $1/\lambda$ for the constant K yields the behavior of the tangent as $K\rightarrow\infty$. Similar expressions are obtained except that the roles of the zeros and poles are interchanged. As an example of pole-zero patterns, Fig. 1 has the initial tangent vectors as indicated.

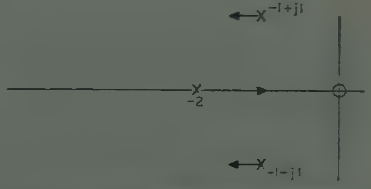

Fig. 1—Tangent vectors of a root locus.

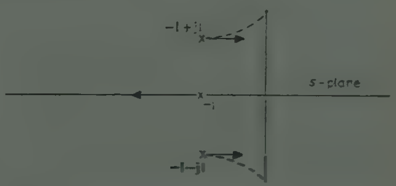

Fig. 2—Pole-zero pattern indicating curvature of the root locus.

The derivative of the tangent vector indicates the amount and direction of turning of the loci. The initial derivative is given by the expression

$$\left.\frac{du}{dK}\right|_{K=0} = 2\frac{Z(s)Z'(s)}{[P'(s)]^2} - \frac{Z^2(s)P''(s)}{[P'(s)]^3}.$$

Use of this formula is restricted to the special case of no zeros in the finite s plane. In this case $Z(s)=1$ and

$$\left.\frac{du}{dK}\right|_{K=0} = u^3(s)P''(s).$$

The pole-zero pattern of Fig. 2 has tangent

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vectors as indicated. Use of the curvature relation indicates that the upper pole curves to the left.

The tangent vector and the curvature of the tangent vector are of interest in that they indicate the direction and curvature of a root locus. The magnitude of the tangent vector indicates the rate of motion of the roots for incremental changes in gain or other circuit parameters.

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A Proposed Technique for the Improvement of Range Determination with Noise Radar*

In the above paper,[1] Bourret pointed out that a very sharp output could be obtained from a noise radar by using for the transmitted signal a bell-shaped power spectrum

$$\Phi(\omega) = \frac{P\beta/\pi}{\beta^2 + (\omega - \omega_0)^2} \tag{1}$$

where P is the total power and β is the distance on either side of ω_0 to the half-power point, and correlating this signal with the double derivative.

It is shown that the autocorrelation function $R(\tau)$ of (1) is

$$R(\tau) = P \cos \omega_0 \tau e^{-\beta|\tau|}. \tag{2}$$

This particular $R(\tau)$ has a cusp at $\tau = 0$, so that its first derivative has a jump discontinuity and the second derivative has the character of an impulse function going to infinity.

The mathematics of the paper appears to be correct, but the physics of the problem leads intuitively to question the basis of the assumption as to whether an approximation to the ideal result can be reached even as a rough approximation.

The literal form of the energy spectrum (1) is impractical since the spectrum extends to infinity. If it were possible to produce and use a spectrum extending to infinity, there undoubtedly would be found a large number of functions which would provide all kinds of desirable results. The only value would lie in the possibility of being able to produce a practical approximation. But that involves a totally different mathematical problem which the paper has not touched. One should really work with a power spectrum of finite bandwidth. Then

$$R(\tau) = \int_0^w \Phi(\omega) \cos \omega\tau d\omega. \tag{3}$$

In this case, differentiation under the integral sign is permissible and one finds that

$$R'(\tau) = -\int_0^w \omega\Phi(\omega) \sin \omega\tau d\omega \tag{4}$$

so that $R'(0) = 0$. In other words, no cusp is observed and $R(\tau)$ has a maximum with slope 0.

This is true no matter how large a bandwidth is selected so that the cusp can never be achieved. This case is, mathematically speaking, an example of non-uniform convergence. One can proceed further and find

$$R''(\tau) = -\int_0^w \omega^2\Phi(\omega) \cos \omega\tau d\omega \tag{5}$$

from which it follows that

$$R''(0) = -\int_0^w \omega^2\Phi(\omega) d\omega. \tag{6}$$

Coupled with the fact that a double differentiation will introduce a great deal of noise into the system, the utility of the method is indeed doubtful.

From (6) it is evident that $R''(0)$ is infinite for infinite bandwidth. This again shows that this method only applies to nonpractical problems.

The mathematical problem of finding an optimum for finite bandwidth has not as yet been formulated rigorously.

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* Received by the IRE, February 4, 1958.

[1] R. Bourret, Proc. IRE, vol. 45, p. 1744; December, 1957.

Estimates of Entropy of a Message Source*

Shannon[1] has shown that, for an ergodic, finite-state message source

$$F_N \leqq G_N, \tag{1}$$

where F_N is the conditional entropy of the next symbol when the preceding $(N-1)$ symbols are known, and G_N is the entropy per symbol of blocks of N symbols. The purpose here is to derive a sequence of related inequalities.

Thus, let $F_N{}^R$ be the conditional entropy (per symbol) of sequences of length R when the preceding sequence of length $(N-R)$ is known.

Symbolically,

$$F_N{}^R = \frac{-1}{R} \sum_{i,j} P(B(N-R, i), B(R, j)) \log P(B(R, j)/B(N-R, i)), \tag{2}$$

where

$B(K, i)$ = the ith sequence of length K
$P(X)$ = probability of sequence X,
$P(X, Y)$ = probability of sequence X followed by sequence Y,
$P(X/Y) = P(Y, X)/P(Y)$ = conditional probability that sequence X follows sequence Y, given Y.

Note that, in terms of Shannon's notation,

$$F_N{}^1 \equiv F_N, \qquad F_N{}^N \equiv G_N. \tag{3}$$

We shall prove that

$$F_N{}^{R+1} \geqq F_N{}^R, \quad (R = 1, 2, \cdots, N-1). \tag{4}$$

From (2) and (4), one readily obtains

$$\begin{aligned} F_N{}^R &= \frac{N}{R} G_N - \frac{(N-R)}{R} G_{N-R} \\ &= \frac{1}{R} (NG_N - (N-R)G_{N-R}). \end{aligned} \tag{5}$$

But Shannon[1] has shown that

$$NG_N = \sum_{K=1}^{N} F_K.$$

Hence (5) becomes

$$\begin{aligned} F_N{}^R &= \frac{1}{R} \left(\sum_{K=1}^{N} F_K - \sum_{K=1}^{N-R} F_K \right) \\ &= \frac{1}{R} \sum_{K=N-R+1}^{N} F_K. \end{aligned} \tag{6}$$

Replacing R by $(R+1)$ in (6) and subtracting yields

$$\begin{aligned} &F_N{}^{R+1} - F_N{}^R \\ &= \frac{1}{R(R+1)} \left(R \sum_{N-R}^{N} F_K - (R+1) \sum_{N-R+1}^{N} F_K \right) \\ &= \frac{1}{R(R+1)} \left(RF_{N-R} - \sum_{N-R+1}^{N} F_K \right), \\ &= \frac{1}{R(R+1)} \left(\sum_{K=N-R+1}^{N} (F_{N-R} - F_K) \right). \end{aligned} \tag{7}$$

But, as Shannon has pointed out,[2] F_N is a monotonic decreasing function of N. Hence (7) is nonnegative, and (4) is proved.

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* Received by the IRE, April 21, 1958.

[1] C. E. Shannon, "The Mathematical Theory of Communication," University of Illinois Press, Urbana, Ill.; 1949.

[2] *Ibid.*, p. 84.

Minimum Weight Solenoid Systems*

As pointed out by Worcester *et al.*,[1] solenoids constructed from aluminium result in a combined coil plus power supply weight which, for correct design, is less than that of the corresponding system with a copper coil, up to a certain coil size, even though the aluminium coil requires more power. However, it can be shown as follows that the advantage is never very great and exists only for coils which have rather small values of R, the ratio of the external to internal diameter. These occur in minimum weight designs only for low-field requirements or large internal diameters.

Worcester, *et al.* use a linear relation beeen the power supply weight and the wer, but a more general relation of the m

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* Received by the IRE, May 5, 1958.

[1] W. E. Worcester, A. L. Weitzmann, and R. J. Townley, "Lightweight aluminium foil solenoids for traveling-wave tubes," IRE Trans. on Electron Devices, vol. ED-3, pp. 70–74; January, 1956.

$$W_p = \alpha \cdot P^\beta$$

1 be handled without difficulty and is eded in practical cases.

Power required by the coil is given by[2]

$$P = \Omega\left(\frac{R+1}{R-1}\right)$$

iere Ω is proportional to the field squared, e length of the coil, and the resistivity of e material, and so the total weight is

$$W_T = \alpha\Omega^\beta\left(\frac{R+1}{R-1}\right)^\beta + d(R^2-1)$$

iere d is proportional to the density of the il, its length, and its internal radius uared.

By differentiation, the condition that the stem shall have minimum weight is

$$\frac{\alpha\beta\Omega^\beta}{d} = R(R-1)^2\cdot\left(\frac{R+1}{R-1}\right)^{1-\beta}$$

1d eliminating $\alpha\Omega^\beta$ from the weight equaon gives the simpler form for minimum eight,

$$W_T = d(R^2-1)\left(\frac{R}{\beta}+1\right).$$

ull treatment of these equations cannot be iven here, but consider the limiting forms f the last two equations when the radius atio is taken as $1+r$ with r small.

$$\frac{\alpha\beta\Omega^\beta}{d} \simeq 2^{1-\beta}\cdot r^{1+\beta}$$

$$W_T \simeq 2rd\left(1+\frac{1}{\beta}\right).$$

can be eliminated immediately giving

$$W_T = \text{constant} \times (\Omega d)^{\beta/1+\beta}.$$

Thus, the weight ratio for minimum weight ystems of different materials can be expressed in terms of a function of the resistivty and density ratios only.

$$\frac{W_1}{W_2} = \left(\frac{\Omega_1}{\Omega_2}\cdot\frac{d_1}{d_2}\right)^{\beta/1+\beta}.$$

f suffix 1 refers to copper and 2 to aluminum this ratio is 1.35 for $\beta=1$.

Similarly, by using the limiting forms for arge R, it follows that the weight ratio depends only on the resistivity ratio

$$\frac{W_1}{W_2} = \left(\frac{\Omega_1}{\Omega_2}\right)^\beta$$

vhich is 0.56 for $\beta=1$.

Thus, copper coil systems are 35 per cent ieavier for near-unity radius ratios but 44 er cent lighter for large radius ratios. In etween, the ratio can be shown to decrease teadily with increasing radius ratio.[3]

If the main weight of the power supply is lue to a transformer, which is often the case, then it can be shown that $\beta=\frac{3}{4}$ is the correct index for the weight-power law and the corresponding weight ratios are 1.30 and 0.65 in the two limits, which is a narrower range than before. With such relatively insignificant differences in weight it would seem that copper coils are to be preferred in view of the smaller size of both coil and power supply.

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[2] R. C. Glass and P. Gottfeldt, "Aluminium foil olenoids for traveling-wave tubes," IRE Trans. on Electron Devices, vol. ED-4, p. 186; April, 1957.

[3] G. M. Clarke, "Weight aspects of coils for magetic fields," to be published in *Electronic and Radio Engineer*.

Various Definitions of the Delta Entities*

I should like to make some comments in connection with the discussion on "the Dirac delta function δ."[1,2] Before deciding what "the δ" really means it is better to speak quite generally about "the delta entity" or "the delta entities." There are many similar entities like "the delta"; *e.g.*, the symbolical σ functions of Paul Lévy[3] or other entities from the quantum physics.

The delta entity can be studied from different points of view which do not eliminate one another:

either it is a *point pseudofunction* (the point standpoint),

or a *distribution* in the sense of Laurent Schwartz[4] (the functional standpoint),

or a *class of almost everywhere equal real functions* in the sense of Heinz König[5] (the abstract algebraical standpoint),

or a *pure symbol* (the symbolical standpoint).

Sketching the theory of the delta pseudofunction we must first answer two questions:

Under what conditions does the symbol $+\infty$ *become a real (infinite) number?*

Why is not the delta entity a (single-valued real) point function of a real independent variable?

To find the exact response one must not only analyze the logical definition of the concept $+\infty$ and of the point function, but must also take into account the manner in which we really use them in the mathematical analysis.

The application of $+\infty$ is based on two principles:

First, in a given mathematical or physical problem P, the number $+\infty$ is always a unique result of a limiting process well-defined in P.

Second, for the calculation with $+\infty$, there exist well-defined arithmetical rules *not dependent* on the limiting process in the first principle; *e.g.*, $a+(+\infty)=+\infty$, where a = any real finite number.

For the concept, "the point function," there are three marks:

1) The first essential mark of the concept is the pure fact of a correspondence of a finite or infinite real number $f(t)$ to a point t from the well-defined point set E. This mark tells us nothing about the realization of this correspondence.

2) The second essential mark is that the correspondence of $f(t)$ to t must be *invariant* with respect to the specifications of the way in which we realize it.

3) The additional mark indicates what the relation $f(t_0)=+\infty$ should mean. We explain it generally. Let t_0 be a (finite or infinite) real point; it need not belong to E. One states that

$$\left.\begin{array}{l}\text{the function } f(t) \text{ has in } t_0 \text{ the value } f(t_0)\\ \quad\text{or } f(t_0+) \text{ or } f(t_0-) \text{ equal to } +\infty\\ \\ \text{or}\\ \\ \text{the supremum of } f(t) \text{ in } t_0 \text{ is } \bar{f}(t_0) \text{ or}\\ \quad\bar{f}(t_0+) \text{ or } \bar{f}(t_0-) \text{ equal to } +\infty\end{array}\right\}(+)$$

if in every two, right, or left-sided neighborhood of t_0, there exists in E a sequence of one or another different points

$$\tau_1, \tau_2, \tau_3, \cdots \to t_0$$

in which

$$f(\tau_1) < f(\tau_2) < f(\tau_3) < \cdots \to \xi,$$

and if the number ξ is equal to $+\infty$ and defines at least one of the six values (+).

In other words mark 3 indicates that the limiting process by which the number $f(t_0)\equiv+\infty$ is defined, *directly depends on* the fact of the correspondence of the values $f(t)$ to the points t from E.

If we deny some of the marks 1–3 above, then $f(t)$ will be defined as a (single-valued real) *point pseudofunction* (of a real independent variable). The name "pseudofunction" was coined by Doetsch.[6] Sometimes one speaks also about "an improper function". We define it by these conditions:

4) Mark 1 above holds good.

5) Mark 2 changes in the negative [non-β]; the correspondence of $f(t)$ to t *depends on* the way in which it is realized.

6) The additional mark 3 can (but not necessarily must) be valid.

Thus, if a correspondence is realized by two essentially different ways, then we have two different point pseudofunctions. The fact of a correspondence is the same, but the way of its realization essentially determines the properties of the pseudofunction under consideration.

Let us start with the unit step function

$$U(t, k) = \begin{cases} 1 & \cdots t > 0\\ k & \cdots t = 0\\ 0 & \cdots t < 0\end{cases}$$

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* Received by the IRE, February 24, 1958; revised manuscript received, March 21, 1958.

[1] R. A. Johnson, "A note concerning the dirac delta function," Proc. IRE, vol. 44, pp. 1058–1059; August, 1956.

[2] P. A. Clavier, R. A. Johnson, and R. B. Lackey, "The Dirac delta function," Proc. IRE, vol. 44, pp. 1876–1877; December, 1956.

[3] P. Lévy, "Une nouvelle classe de fonctions symboliques: les σ-fonctions," *Bull. Sci. Math.*, vol. 80, pp. 83–96; May–June, 1956.

[4] L. Schwartz, "Théorie des distributions," *Actual. scient. industr.*, part I, p. 1091, 1950; part II, p. 1122, 1951.

[5] H. König, "Neue Begründung der Theorie der 'Distribution' von L. Schwartz," *Mathem. Nachricht.*, vol. 9, pp. 129–148; 1953.

[6] G. Doetsch, "Handbuch der Laplace-Transformation," Bd. II, 1. Abt., Birkhäuser, Basel-Stuttgart, Germany; 1955.

where k is a real constant from the interval $-\infty < k < +\infty$. Every value of the parameter k defines a certain function $U(t, k)$. Two different values k_1, k_2 define two different step functions.

It is necessary to distinguish between a certain step function and the class (set) of all these functions. Therefore we have in general two kinds of properties. Let K be a class of the elements e. We designate the property A as *individual*, when it refers to the certain element $e \in K$ only; A is a *class property*, when it refers to all elements e which are considered as a whole set K. If the property A depends on a certain value of k, this is called the *individual property* of the mathematical entity under consideration. When A is not dependent on k, then A is a class property of these entities.

At any point t from $-\infty < t < +\infty$, one can compute the derivative of $U(t, k)$ according to the classical definition. Taking $+\infty$ as a number we can imply a correspondence of elements from the set of two elements $\{0, +\infty\}$ to elements of the set of all real finite numbers. Therefore it is permitted (as the result of this correspondence) to define the following entity

$$\delta(t, k) = \begin{cases} \dfrac{dU(t, k)}{dt} \text{ (the both-sided derivative)} \\ \qquad\qquad\qquad \text{if } 0<k<1, \\ \dfrac{d^+U(t, k)}{dt} \text{ (the right-sided derivative)} \\ \qquad\qquad\qquad \text{if } k \leq 0, \\ \dfrac{d^-U(t, k)}{dt} \text{ (the left-sided derivative)} \\ \qquad\qquad\qquad \text{if } k \geq 1. \end{cases}$$

This correspondence itself is a class property belonging to all entities $\delta(t, k)$. Every $\delta(t, k)$ really has mark 1, but it is not a point function because of the validity of mark 5 and the nonvalidity of mark 3. $\delta(t, k)$ is a point pseudofunction and cannot be treated by the methods appropriate to the point functions.

For the physical applications, it seems to be useful to restrict the values of the parameter k and to introduce the following definition:

The point pseudofunction $\delta(t, k)$ is called the *unit impulse pseudofunction*, if $0 \leq k \leq 1$; the point pseudofunction with the value $k = 1/2$ is called the *symmetrical Delta pseudofunction* or the *Dirac (improper) function*.

Delta pseudofunctions may be obtained in a more routine fashion using the limits of certain rectangles. If we introduce the number ρ by

$$\rho = 1 - k$$

then, geometrically, ρ is the portion of the area of rectangles under consideration situated on the right half plane. This number coincides with that of Johnson.[1]

The theorems governing the theory of the delta pseudofunctions may be stated by the use of the Riemann-Stieltjes or generally of the Lebesgue-Stieltjes integration.

Concerning the Laplace transform we have the following statement: for the pseudofunction $\delta(t, k)(0 \leq k \leq 1)$, the one-sided Laplace transform has a meaning only when $k = 0$; if $0 < k \leq 1$, this transform has no meaning. But the two-sided Laplace transform always has a meaning for $0 \leq k \leq 1$.

Taking the delta entity as a distribution it is clear that the theory of distributions deals only with the class properties of the delta pseudofunctions, so that we omit here their individual ones. This has two important effects for the engineering applications of the delta entities:

First, in studying the impulse phenomena and the phenomena of the automatic control technique, engineers are primarily interested in their individual properties. They incline to consider the point pseudofunctions $\delta(t, k)$ rather than the delta distribution.

Second, if we want to use the delta distribution, it would be necessary to define the notions of the impulse and automatic control technique in a new way with respect to the class properties of the phenomena under consideration, not with respect to their individual properties as is usual nowadays. Such research would be very useful for any engineering theory.

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Some Comments on Minimum Triggering Signals*

Another theorem on minimum energy triggering signals, which is at least of academic interest, may be stated as follows.

Given a lossless network driven from a constant voltage source $e_1(t)$ and terminated in a resistor (see Fig. 1), the optimum triggering signal $e_1(t)$, which will make the voltage across the terminating resistor a value of e_0 at time t_0, is a doublet at t_0 if $g_{12}(+0) \neq 0$ and $g_{12}(t)$ are bounded. Also, the minimum energy consumed is zero. $g_{12}(t)$ is the impulse response of the network.

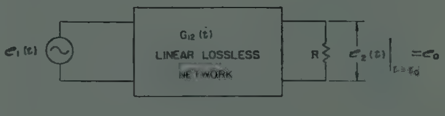

Fig. 1.

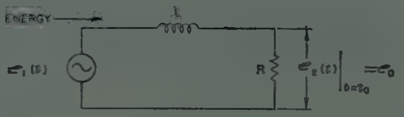

Fig. 2.

Consider a driving function $e_1(t)$ as a positive impulse at $t=0$ followed by a negative impulse at $t=\Delta t$, and let $\Delta t \to 0$. The energy consumed by the terminating resistor, assuming the output voltage reached the value e_0 (this is easily done since it is assumed that $g_{12}(+0) \neq 0$) is as follows:

$$E = \frac{1}{R} \lim_{\Delta t \to 0} \left\{ \int_0^{\Delta t} \frac{e_0^2 g_{12}^2(t)}{g_{12}^2(+0)} dt + \int_{\Delta t}^{\infty} \left[\frac{e_0 g_{12}(t)}{g_{12}(+0)} - \frac{e_0 g_{12}(t-\Delta t)}{g_{12;}(-0)} \right] dt \right\}$$

$$E = \frac{1}{R} \lim_{\Delta t \to 0} \left\{ \int_0^{\Delta t} \frac{e_0^2 g_{12}(t)}{g_{12}^2(+0)} + \int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}^2(t)}{g_{12}^2(+0)} dt + \int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}^2(t-\Delta t)}{g_{12}^2(+0)} dt - 2 \int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}(t) g_{12}(t-\Delta t)}{g_{12}^2(+0)} dt \right\}.$$

Now, if $g_{12}(t)$ is bounded, and $\Delta t \to 0$:

$$\int^{\Delta t} \frac{e_0^2 g_{12}(t)}{g_{12}^2(+0)} dt \to 0$$

$$\int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}^2(t-\Delta t)}{g_{12}^2(+0)} dt$$

$$\to \int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}(t) g_{12}(t-\Delta t)}{g_{12}^2(0)} dt$$

$$\to \int_{\Delta t}^{\infty} \frac{e_0^2 g_{12}^2(t)}{g_{12}^2(+0)} dt.$$

Hence in the limit,

$$E = 0 \quad \text{and} \quad e_1(t) \text{ is a doublet.}$$

The theorem is easily extended to cover certain classes of lossy networks; that is, if the impulse response across *each* resistor in the network is not zero at $t=+0$ and is bounded, then the optimum signal is a doublet and the energy consumed is zero.

Although the above theorem and Beattie's work[1] are fundamental and interesting, they are of little practical importance, since the optimum signal usually requires that the signal source is capable of *absorbing energy*. That is, the generator tries to get back the energy it has put into the network. This is usually not feasible. For example, a radar receiver cannot send unused energy back to the transmitter. It would certainly be of more practical interest if the signal optimization were carried out not only subject to the constraint that the output voltage (or current) reaches a triggering level, but also the constraint that the signal source is capable of delivering but not absorbing energy. For example, find the optimum signal for the circuit of Fig. 2 subject to the above conditions. (Note that the doublet is the optimum signal under ideal conditions.) The optimum signal obviously must deliver at least

$$E_{\min} = \tfrac{1}{2} L \frac{e_0^2}{R^2}.$$

Now assume that the input signal is an impulse. Then,

$$E = \int_0^{\infty} \frac{e_0^2}{R} e^{-(2R/L)t} dt = \tfrac{1}{2} L \frac{e_0^2}{R} = E_{\min}$$

Hence, the optimum signal for this simple case under the additional constraint, that

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* Received by the IRE, April 28, 1958.

[1] L. A. Beattie, "Minimum energy triggering signals," Proc. IRE, vol. 46, pp. 751–757; April, 1958.

he signal source can only deliver energy, is n impulse.

Perhaps the most interesting situation is vhere one has control over both the transnitter and receiver, as is often the case. This rings to mind the question, "What is he optimum receiver-transmitter combinaion?"

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A Low-Noise Nonlinear Reactance Traveling-Wave Amplifier*

Nonlinear reactance amplification at high frequencies is currently receiving widespread interest for two major reasons:

1) Low-loss ferromagnetic materials and variable capacitance elements (semiconductor diodes) now available are suitable for nonlinear reactance operation at UHF and microwave frequencies.

2) The variable reactance amplifier does not depend on resistive elements for operation. Hence, it should be capable of yielding very low noise figures without refrigeration.

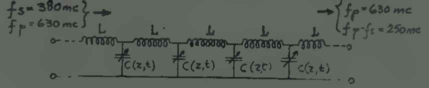
The general energy relations for nonlinear reactance amplification have been developed by Manley and Rowe.[1] Tien and Suhl have recently presented an analysis of traveling-wave amplification by means of nonlinear reactances[2] and have given a detailed discussion of the ferromagnetic type amplifier.

The purpose of this letter is to present some of the results obtained with a first experimental model of a traveling-wave variable reactance amplifier using nonlinear capacitances and designed for operation at UHF. The amplifier was designed and built late in 1957 and tested early in 1958. It operates under the following conditions:

Signal frequency: 380 mc
Pump (energizing) frequency: 630 mc
(Idler frequency: 250 mc)
Forward-signal gain: 10 to 12 db (signal and pump traveling in the same direction)
Conversion gain (380 to 250 mc): 8 to 10 db
Reverse-signal gain: −3 to −6 db (signal and pump traveling in opposite directions)
Pump power: 1 to 2 mw
Bandwidth: 10 to 20 mc
Noise figure: 3.5 db.

The choice of signal and pump frequencies was governed by the availability of associated equipment (filters, etc.).

The reader is referred to Tien and Suhl[2] for the theory of operation of the nonlinear reactance traveling-wave amplifier. The amplifying structure used resembles that shown in Tien and Suhl's Fig. 2 which is reproduced here.



Four diffused-junction nonlinear capacitance silicon diodes having low resistive loss were used. These are described by Uhlir[3] and Bakanowski, *et al.*[4] The circuit was designed to propagate with nearly equal velocities the signal, pump, and idler $(fp-fs)$ frequencies. With the sum frequency $(fp+fs=1010$ mc) reactively terminated, the operation of the amplifier corresponds to the "inverting modulator" case of Manley and Rowe's paper.[1] A more detailed presentation of the results obtained with the above amplifier and others currently under investigation is in preparation.

The writer wishes to express his thanks to A. Uhlir, Jr., for furnishing the variable capacitance diodes and to W. W. Mumford for his guidance and help.

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* Received by the IRE, May 6, 1958.

[1] J. M. Manley and H. E. Rowe, "Some general properties of nonlinear elements—Part I," Proc. IRE, vol. 44, pp. 904–913; July, 1956.

[2] P. K. Tien and H. Suhl, "A traveling wave ferromagnetic amplifier," Proc. IRE, vol., 46, pp. 700–706; April, 1958.

[3] A. Uhlir, Jr., "The potential of semiconductor diodes in high-frequency communications," Proc. IRE, vol. 46, pp. 1099–1115; June, 1958.

[4] A. E. Bakanowski, N. G. Cranna, and A. Uhlir, Jr., "Diffused silicon and germanium nonlinear capacitors," presented at IRE-AIEE Semiconductor Device Res. Conf., Boulder, Colo., July, 1957.

The Electron Optical Action of an Annular Aperture Lens*

Until now, the only formula available to describe the deflection of an electron in an annular aperture lens has been the one derived empirically by Glewwe.[1] The purpose here is to present the derivation of an alternate and simpler formula which nevertheless serves to verify the work of Glewwe.

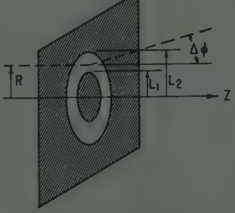

Fig. 1—Annular lens geometry.

In the annular lens shown in Fig. 1, the inner and outer radii of the aperture are L_1 and L_2, respectively, and the lens is at potential V with respect to the cathode from which electrons originate. The dashed line shows the trajectory of an electron entering the lens parallel to the axis and at a distance R from it. If E_z is the axial electric field existing on the left side of the plane in the absence of the slit, and if there is no field to the right of the plane, then Glewwe's formula for the deflection $\Delta\phi$ of the trajectory is

$$\tan(\Delta\phi) = \frac{-E_2L_2}{2V}\left[1-(1-L_1/L_2)^{1.5}\right]\ln\frac{R}{\sqrt{L_1L_2}}. \quad (1)$$

This is a thin lens formula and is based on the empirical observation that there is no deflection of those electrons at $R=\sqrt{L_1L_2}$.

We can derive a simpler formula in the standard way starting with this same observation. It is apparent from this fact that electric field lines which, in the uniform part of the field, lie outside $\sqrt{L_1L_2}$ must fringe outward and terminate on the outer part of the lens, while those inside $\sqrt{L_2L_1}$ must terminate on the inner part of the lens. Since no flux crosses the surface $R=\sqrt{L_1L_2}$, we can construct an annular pill box with one curved surface at R, and the other at $R=\sqrt{L_1L_2}$. The ends are placed sufficiently far from the lens for the box to encompass the entire range of field distortion due to the aperture (Fig. 2).

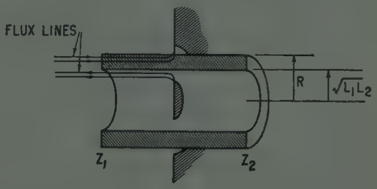

Fig. 2—Illustrating the application of Gauss' law for an annular lens.

The flux entering the curved surface at R must equal that leaving the annular end of the box, (neglecting any space charge) so that

$$-2\pi R\int_{z_1}^{z_2}E_Rdz = -\int_{\sqrt{L_1L_2}}^{R}2\pi RE_zdR. \quad (2)$$

The total radial impulse given an electron at R is

$$m\Delta v_R = e\int_{t_1}^{t_2}E_Rdt = e\int_{z_1}^{z_2}\frac{E_R}{v_z}d_z. \quad (3)$$

Assuming that v_z and R are unchanged as the electron passes through the lens (thin lens approximation) we find from (2) that

$$\Delta v_R = \frac{e/m}{v_z}\frac{E_z}{R}\int_{\sqrt{L_1L_2}}^{R}RdR. \quad (4)$$

Integrating, and making use of $v_z^2=-2e/m\ V$

$$\frac{\Delta v_R}{v_z} = \tan(\Delta\phi) = -\frac{E_z}{2V}\frac{R^2-L_1L_2}{2R}. \quad (5)$$

Eq. (5) has properties similar to that of Glewwe's formula. In the limit as L_1 and L_2 become large and $L_1/L_2\rightarrow 1$, both reduce to the well-known Davisson formula for a slit.[2] Furthermore, both formulas predict

* Received by the IRE, April 21, 1958.

[1] C. W. Glewwe, "Some properties of an annular electron lens," M. S. thesis, University of Minnesota, Minneapolis, Minn.; 1955.

[2] K. R. Spangenberg, "Vacuum Tubes," McGraw-Hill Book Co., Inc., New York, N. Y., p. 354; 1948.

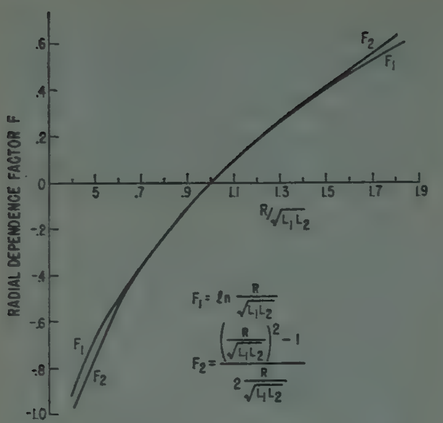

Fig. 3—Relative deflection as a function of radius predicted by the two lens formulas.

equal and opposite deflections for electrons at radii R_1 and R_2 so that

$$R_1R_2 = L_1L_2.$$

The factors in both formulas showing the dependence of tan $(\Delta\phi)$ on R are compared in Fig. 3 which illustrates the equivalence of the two expressions in the usual range of interest. For many practical cases the factor $[1-(1-L_1/L_2)^{1.5}]$ in (1) is reasonably close to 1.

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Pulse Modulation Transmitted through a Linearly Modulated Transit-Time Device*

A recent publication[1] discusses the use of transit-time modulation, by linear sawtooth waveforms, to accomplish frequency translation. The analysis presented has been carried out by Fourier integration over the modulation cycle, and, therefore, is restricted to problems which are quasistationary with respect to the modulation waveform. Some interesting properties of the system are lost by such an approach. The following paragraphs present a comprehensive discussion of the phenomena, without attempting analytical investigation of the problems encountered. They appear straightforward but tedious, and their evaluation would exceed the limits of the present space.

Extension of Previous Analysis

The notation of Cumming[1] is used to facilitate comparison. Referring to his Figs. 4 and 5, we draw the analogous diagram for *symmetrical* sawtooth modulation.

For convenience we assume commensurate periods so that

$$T_m = kT_i \tag{1}$$

where k is a positive integer, but this restriction will be dropped in the most general case. Fig. 1 shows that neither overlapping nor holes appear in the train of samples constituting the ouput, at least for moderate amounts of modulation which will be assumed. In this respect our Fig. 1 differs from Figs. 4 and 5 of Cumming.[1]

The sampling points on the input-line of Fig. 1 represent the zero crossings of a continuous signal of frequency $f_i=1/T_i$, entering the transit-time modulated device. The phase modulation converts the signal into two pulse trains of frequencies $f_{o1}=1/T_{o1}$ and $f_{o2}=1/T_{o2}$, respectively, interlaced at a repetition rate $f_m=1/T_m$. The pulses of one train fill the gaps between the pulses of the other, and vice versa. As indicated in Fig. 1, the pulses of the trains contain equal numbers of carrier cycles and, therefore, at the output are unequal in width and amplitude, in the fashion of an equal total energy per pulse relation.

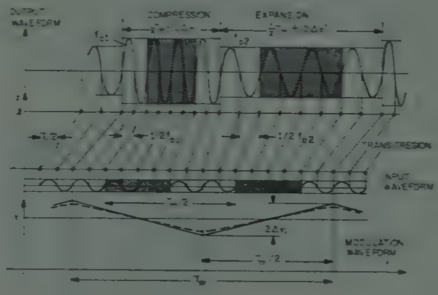

Fig. 1—Transmission of a sinusoid of frequency f_i through the transit-time device.

If condition (1) is not met, the carrier phase will vary from pulse to pulse of each train with respect to the envelope. In pulse modulation this is unimportant, since we shall integrate over the *carrier cycle* in the demodulation process. (In other words, we are only interested in the envelope of the pulses.) The basic difference in the approach of Cumming[1] is that Fourier integration is extended over several periods of the *modulation-waveform*,[2] and thus his coherence condition (1) results, which becomes irrelevant for pulse modulation.

The foregoing considerations show that pulse modulation constitutes a very natural utilization of the method, since signals may be restricted to the straight, continuous portions of the modulation cycle. Thus, even for asymmetrical linear sawtooth modulation as discussed by Cumming,[1] the influence of the everpresent, finite flyback interval may be completely eliminated by a pulse scheme. On the other hand, if we choose symmetrical triangular modulation, we are able to make use of both slopes for frequency shift in opposite directions for adjacent pulses. The shaded areas in Fig. 1 illustrate the situation for pulse-modulated input, and represent the signal-on periods.

The required synchronism between pulse train and modulation waveform is readily accomplished, making use of the periodicity of the pulse-train envelope. The relation between frequency shift in the system and the transit-time modulation parameter $\dot{\tau}$ is obtained from elementary considerations as

$$f_{o1,2} = \frac{f_i}{1 \mp \dot{\tau}} \doteq f_i(1 \pm \dot{\tau}), \quad \dot{\tau} \ll 1, \tag{2}$$

where $\dot{\tau} = -4|\Delta\tau|f_m$ for symmetrical triangular modulation. Eq. (2) is the analogous expression to (2) in Cumming's paper. The difference is that we may assign $\dot{\tau}$ any practical value, since we are not restricted by the coherence-condition (1) of Cumming. Introducing the $\dot{\tau}$ just defined in his (1), we have

$$\bar{n} = -\dot{\tau}f_o/2f_m. \tag{3}$$

Overlapping of significant regions of the pulse spectra is prevented if we assign $\bar{n}$ a value between three and five. Fig. 2 illustrates the situation on hand of the unshifted and both shifted spectra, for two typical values of $\bar{n}$.

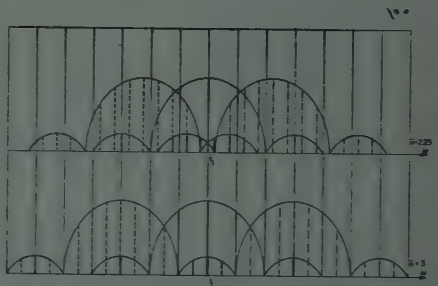

Fig. 2—Pulse spectra for $\bar{n}=2.25$ and 3.

The spectral distributions are sketched for square-wave envelope with repetition rate $2f_m$, and fixed carrier frequency f_i of the input pulses. Note that the line spacing is halved in the shifted spectra, according to the superposition of two pulse trains of repetition rate f_m. Analysis would show a phase relationship between components, due to the periodicity of the original waveform. In Fig. 2 we merely intend to present a crude estimate of crosstalk. It seems apparent that values $\bar{n}=(2n+1)/4$, $n=0,1,2,\cdots$, prevent coincidence of significant components of the original, and either one of the shifted spectra. Even under practical conditions, these values should assure minimum crosstalk between channels.

The residual overlapping of the pulse spectra represents the only source of first-order crosstalk in the device, as long as we assume linear transmission. Other effects are of a CW nature and readily eliminated in the demodulation process.

The method described seems to be most applicable at microwave frequencies with pulse-repetition rates in the megacycle range. Experimental investigations by others[1,3] demonstrates feasibility of $\bar{n}=1$ with conventional traveling-wave tubes. It seems realistic to expect $\bar{n}=2$ with present tubes, and slight changes in tube design should lead to satisfactory performance

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* Received by the IRE, May 2, 1958.

[1] R. C. Cumming, "The serrodyne frequency translator," Proc. IRE, vol. 45 pp. 175–186; February, 1957.

[2] The conventional spectrum viewpoint of frequency modulation cannot provide the required time resolution, and one must investigate the time-functions proper.

[3] D. R. Bellis and R. A. Huggins, "Phase Modulation of Traveling Wave Tubes," Eng. Notes, Huggins Lab., Menlo Park, Calif.; March, 1957.

around 3 to 4 for $\bar{n}$. This would chiefly involve lengthening of the transit time. Narrow-band filters, to separate the resulting pulse channels, are readily constructed.

From (3) we realize that for these practical assumptions $\dot{\tau} \ll 1$, such that with $f_i \dot{\tau} = \Delta f_i$ we may rewrite (2)

$$f_{o1,2} \doteq f_i \pm \Delta f_i. \qquad (4)$$

This implies negligible frequency asymmetry of the shifted pair, and analogously amplitude and width of the pulses will experience negligible change.

All our considerations so far have been based on symmetrical triangular transit-time modulation, but ultimately we shall employ the linear portions of a sine wave, as indicated by the dotted curve in Fig. 1. This sine wave may be directly obtained from one demodulated pulsetrain, at f_{01} for example, and the system is self-synchronizing, as soon as a signal is present. Since the sine wave introduces a certain deviation from linearity of the modulation waveform, distortion will arise, which is expected to be tolerable. Also, since the significant change in waveform occurs during the pulses only, the effective $\bar{n}$ for the sine wave is larger than $\bar{n}$ for a linear sawtooth of equal peak amplitude, due to the larger $\dot{\tau}$.

Thus we realize that for pulse modulation schemes the ideal transit-time modulation, waveform would be trapezoidal, the slopes being restricted to the duration of the pulses. With respect to spectral separation, this will assure best use of the total phase shift available in the transit-time device. Pulse modulation, combined with sinusoidal transit-time modulation, should render a very good approximation of this ideal case. As indicated in Fig. 3, only the portions of the modulation voltage, which correspond to the pulse-on intervals, make contributions to the output. Distortion during the rounded portions of the waveform is irrelevant, since it occurs for no-signal periods. Since $\dot{\tau} = -2\pi\Delta\tau f_m$, the effective $\bar{n}$ is increased by a factor $\pi/2$ over that of the symmetrical linear sawtooth of equal peak amplitude, according to (3).

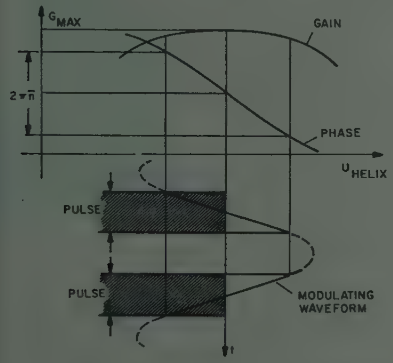

Fig. 3—Transit-time modulation characteristic for a traveling-wave tube.

SPECIFIC APPLICATIONS

Shifting of the Pulse-Carrier Frequency

If RF pulses of essentially arbitrary shape, repetition rate $2f_m$, proper phasing of their envelope with respect to the transit-time modulation as indicated in Fig. 1, and carrier frequency f_i are fed into the system, adjacent output pulses have carrier frequencies $f_i + \Delta f_i$ and $f_i - \Delta f_i$, respectively. Pulses spaced T_m thus experience frequency shift either up or downward, with no undesired components otherwise. The length and height of the pulses are affected according to the percentage of the frequency shift.[4] For $f_i \gg \Delta f_i$ these effects are negligible.

Applications in Frequency-Script Counters or Computers

In a system which employs the carrier frequencies f_i and, for example, f_{01} of the pulses to represent binary states, the device may serve as a shift register. The clock pulses synchronize the transit-time modulation, and no appreciable pulse distortion occurs during the shifting. The repetition rate of the pulses is f_m, their length $T_m/4$, and a time shift $T_m/2$ may be used to accomplish addition or subtraction.[5]

Pulse-Duplexing Scheme

Assume two channels to be represented on a pulse train of carrier frequency f_i by time division, odd pulses denoting channel 1 and even pulses denoting channel 2. A transit-time device may then be employed as a convenient decoder. Sinusoidal or symmetrical triangular transit-time modulation is employed, and the modulation voltage again is readily derived from the signal. The pulses then alternatingly fall on rising or decreasing portions of the modulation period, and the resulting frequency shift converts time division into frequency division. The two channels then are quite easily separated by filters. The inverse procedure may be used for time-division coding.

MULTIPLE REFLEX-PULSE AMPLIFIER

According to Fig. 4, the incoming information is pulse modulated and has a carrier frequency f_i. The pulses are fed into the transit-time modulator which also provides gain for the signal, and employs symmetrical triangular or sinusoidal modulation. Again the transit-time modulation voltage may be derived from the pulse train. Odd and even pulses of the train are shifted upward or downward in frequency, respectively, through junction B enter filter 1 with associated delay MT_m, and through junction A re-enter the transit-time modulator. The delay MT_m is chosen such that each pulse enters the transit-time device under identical modulation conditions, as on its first passage. The procedure is repeated, and after a certain number of recirculations, each of which is associated with delay and signal gain, two adjacent pulses of the train are at carrier frequencies symmetrically located about f_i, and eventually will reach a symmetrical pair $f_i \pm n\Delta f_i$, denoting the limits of the useful band.[6] The signals then enter filter 2,

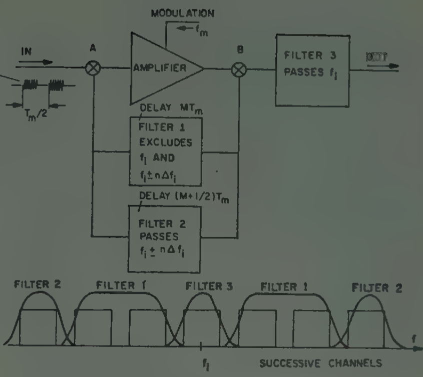

Fig. 4—Block diagram and filter characteristics for the pulse-reflex amplifier.

and the associated delay $(M+\frac{1}{2})T_m$ brings the pulses to slopes of opposite frequency shifting. After an equal amount of total recirculations the pulses will be shifted back to f_i, again experiencing delay and gain at each recirculation, and leave the loop through junction B and filter 3. Pulse deformation due to the amplitude and compression effects is compensated, since individual pulses go through the mechanism both ways.

The system described exhibits certain memory properties, since pulses are circulating in the device for a time given by the total number of recirculations.[7]

To avoid coupling from the highly amplified pulses, which are about to leave the system, to the channels of the low-level incoming pulses, it might be advantageous not to run through the inverse-shifting procedure as just described. Instead, pulses at carrier frequencies $f_i \pm n\Delta f_i$ may be shifted back to f_i with a conventional mixer. With increasing amplification, the amplified spectra move away from the low-level channels, and crosstalk is held to a minimum.

Acknowledgment is due to Dr. W. A. Edson for contributing valuable comments.

V. Met
General Electric Co.
Palo Alto, Calif.

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[4] Large upward frequency results in shortening of RF pulses, which seems also attractive on an energy basis.

[5] M. I. Disman, "Registers and Counters Based on Frequency Memory," Stanford University, Stanford, Calif., Rep. No. TR-19; August 16, 1954.

[6] For this, the deviation from actual symmetry according to (2) will accumulate, but for only a few recirculations and $\dot{\tau} \ll 1$ still presents no problem.

[7] Construction of a frequency-division delay line, utilizing the compounded delay, seems promising.

Phase Dependence of a Ferromagnetic Microwave Amplifier*

An amplifier using polycrystalline yttrium garnet[1] of 75-oersted linewidth has been tested. It is based on the degenerate, two-frequency electromagnetic mode of operation, a special case of that proposed by Suhl.[2] The purpose of this letter is to present

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* Received by the IRE, April 8, 1958.

[1] The garnet was obtained from Harvard University through the courtesy of Prof. C. L. Hogan and Dr. J. E. Pippin.

[2] H. Suhl, "Proposal for a ferromagnetic amplifier in the microwave range," *Phys. Rev.*, vol. 106, pp. 384–385; April 15, 1957.

experimental evidence of the phase-dependent operation of this type of ferromagnetic microwave amplifier.

Since the pulsed pump power and the CW signal input are not necessarily phase coherent, the output level differs from pulse to pulse. An experiment was designed to display on a single oscilloscope trace, the amplifier output pulse and a pulse showing the corresponding phase difference between pump and signal inputs. Fig. 1(a) shows approximately twelve superimposed traces. The amplifier output pulse is on the left and is seen to range between net gain (upward deflection) and attenuation. Fig. 1(b), 1(c), and 1(d) are single trace photographs showing the maximum gain, intermediate gain, and maximum attenuation conditions, respectively, corresponding to maximum, intermediate, and zero amplitudes of the phase-comparison pulses. The phase pulse shows the shape of the magnetron pulse. It is seen that relative phase coherence is maintained over the 0.5-μsec duration of a pulse, as would be expected. Some extraneous high-frequency transients from the pulser are also seen on all the traces.

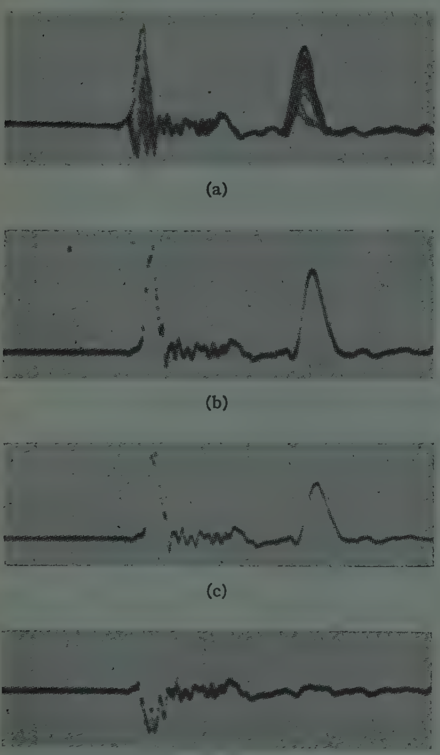
(a)
(b)
(c)
(d)

Fig. 1.

The experimental apparatus is arranged as follows. An X-band magnetron and the sweep of an oscilloscope are triggered by a common single-pulse trigger. A portion of the pump power is added, in a magic tee, to the output of a crystal frequency doubler, which is driven phase coherently by the 4650-mc signal generator. The sum pulse, indicating their relative phases, is detected by a calibrated crystal and displayed on the oscilloscope after passing through a 1.7-μsec delay line. The delay is introduced so that the amplifier output pulse and its corresponding phase pulse can be displayed on the same trace. A variable phase shifter is placed between the crystal doubler and magic tee, and is adjusted so that the phase and amplifier output pulses are simultaneously a maximum.

This experiment was then repeated for a large number of pulses. It was seen that for only one setting of the phase shifter was there a one-to-one correspondence between maximum amplification and maximum phase-pulse amplitude (0 degree phase difference) and between maximum attenuation and zero phase pulse amplitude (180 degrees phase difference). It was also seen that two values of incoming pump-power phase gave zero net amplifier gain. This behavior is consistent with the phase dependence of the lumped circuit analog of the simple parametric amplifier.[3]

The amplifier itself consists of a strip line cavity normal to an X-band waveguide. In this respect it is similar to the one reported by Weiss.[4] The strip line cavity is one wavelength long; its resonant frequency is 4650 mc. The strip is 0.320 inch in width and is shorted at both ends. A garnet disk of 0.30-inch diameter and of 0.050-inch thickness is cemented to each side of the strip at its center. Coupling into and out of the cavity at signal frequency is obtained by means of probes located one-quarter wavelength from each end. X-band waveguide of one-half standard height is used to increase the filling factor of the garnet in the cavity and also to increase the effective pump field. H_{dc} is set for ferromagnetic resonance at pump frequency and is in the plane of the strip. The field direction is at 45 degrees to the long dimension of the strip and to the waveguide. The threshold pump power for oscillation in this amplifier has been observed to be 8-kw peak. For 0.1-mw signal input, a peak gain of 47 db has been observed with a bandwidth of approximately 1 mc.

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F. B. Wang
Hughes Aircraft Co.
Culver City, Calif.

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[3] T. J. Bridges "A parametric electron beam amplifier," Proc. IRE, vol. 46, pp. 494–495; February, 1958.

[4] M. T. Weiss "A solid-state microwave amplifier and oscillator using ferrites," *Phys. Rev.*, vol. 107, p. 317; July 1, 1957.

Analysis of Traveling-Wave Tubes with Tapered Velocity Parameter*

There are several potential applications for the principle of traveling-wave interaction between a beam and a circuit structure in which either the dc beam velocity or the cold circuit phase velocity, or both, is nonuniform, thus yielding a velocity parameter b which is a function of z, the direction of propagation. The case of constant beam velocity and tapered circuit phase velocity may show the way to eliminating undesired backward-wave oscillations in forward-wave amplifiers. For one direction of taper, it appears that the start-oscillation CN is reduced for backward-wave oscillations, thus making possible BW oscillators of reduced size and weight.

The case of variable beam velocity is interesting because of the possibility of designing a backward-wave oscillator in the gun or acceleration region of the tube, thus yielding a minimum size and weight.

Because of the immediate application of the constant beam velocity-tapered circuit velocity case to BW oscillation suppression, an analysis of this situation has been made. Two approaches have been considered. For both methods the assumption of a linearly tapered velocity parameter b was made. One method involves graphical integration of x and y vs b curves plotted from the determinantal equation for the incremental propagation constants derived for the tapered circuit structure case. The other approach, which leads to less laborious numerical computation but is limited to small values of CN, involves finding a power series solution for the RF circuit voltage, RF beam current, and RF beam velocity differential equations, in the manner of Quate.[1] For the case of zero initial current and velocity modulation on the beam, the solution for the RF circuit voltage for forward-wave interaction for $QC=d=0$ takes the form

$$\frac{V(z)}{V(o)} = \exp -j\beta_e\left(1+\frac{b(o)C}{2}\right)z \cdot\left[e^{-j\pi CN(b(o)+2\pi CNT)} - j\,\frac{(2\pi CN)^3}{3!} + j\,\frac{(2\pi CN)^5}{5!}\left(\frac{b(o)^2}{2}+j5T\right) - \frac{(2\pi CN)^6}{6!}(1-j3b(o)T)+\cdots\right] \tag{1}$$

where $b(o)$ is the velocity parameter at $z=0$ and T is the taper constant given by

$$T = \frac{\tau}{\beta_e C^2} \tag{2}$$

where $\beta_e=\omega/u_0$ and τ is defined by the set of circuit equations

$$X = X(o)(1+\tau z)$$
$$B = B(o)(1+\tau z) \tag{3}$$

for the reactance and susceptance per unit length of the equivalent transmission line for the circuit.

For the case of backward-wave interaction it is only necessary to replace $b(o)$ by $-b(o)$ and j by $-j$ in (1). For the case of zero T, (1) reduces to the solution obtained by Quate.

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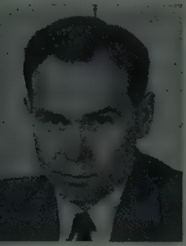
* Received by the IRE, May 14, 1958.

[1] C. F. Quate, "Power Series Solution of Traveling Wave Tube Equations," Bell Telephone Labs., Rep. No. MM-53-1500-36; October 20, 1953.

Contributors



M. P. Bachynski

Morrel P. Bachynski (S'54–M'56) was born on July 19, 1930 in Bienfait, Saskatchewan, Canada. He received the B.E. degree in engineering physics in 1952 and the M.S. degree in 1953, both from the University of Saskatchewan, and the Ph.D. degree from McGill University, Montreal, Canada, in 1955.

Until October, 1955, as a member of the staff of the Eaton Electronics Research Laboratory at McGill he was engaged in investigations concerning aberrations in microwave lens systems. Since that time he has been with the RCA Victor Research Laboratories, Montreal, concerned primarily with short-wave propagation problems.

He now holds the position of head of the Wave Propagation Division.

❖

W. E. Dahlke

Walter E. Dahlke was born in Berlin, Germany, on August 24, 1910. He graduated Dr. phil. in 1936 after having studied physics and mathematics at the University of Berlin. During the following four years, he was a research assistant at the Physical Institute of the University of Jena, Germany. Here he took the degree of Dr. phil. habil. (lecturer) in 1939, working on infrared spectroscopy. In 1940 through 1945 he was a member, and since 1944 the head, of the microwave tube laboratory at the German Aviation Research Establishment in Berlin-Adlershof.

Mr. Dahlke joined Telefunken Laboratory, Ulm, in 1949. As head of a research group he has been working specifically on problems of electron tubes for triode characteristics, tube noise, and oxide cathodes. At present he is giving lectures on electron tubes at the Institute of Technology in Stuttgart.

He is a member of the German Physical Society.

❖

Franz Dlouhy was born on July 10, 1914 in Hainburg, Austria. He joined Telefunken Laboratories, Ulm, Germany, in 1947, where he participated in development work and investigations concerning vacuum tubes. In 1952 he finished his technical training, which had been interrupted by World War II, and received the Diplom Ingenieur from Technische Hochschule, Karlsruhe, Southern Germany.

He is now specifically working on studies on oxide coated cathodes.

F. Dlouhy

❖

E. E. Dreese

Erwin E. Dreese was born in Millbrook, Mich., on September 10, 1895. He received the B.S. degree in electrical engineering from the University of Michigan, Ann Arbor, in 1920, the M.S. degree in 1922, and the degree of Electrical Engineer in 1929.

In 1917 and 1918 he served with the U. S. Army Signal Corps and from 1925 to 1930 was chief engineer of the Lincoln Electric Company, Cleveland, Ohio. Since 1930 he has been professor and chairman of the Electrical Engineering Department at the Ohio State University, Columbus. Since 1937 he has also been editor of technical textbooks for the International Textbook Company and chairman of the board of trustees of the James F. Lincoln Arc Welding Foundation.

He is a member of the American Institute of Electrical Engineers, the American Society for Engineering Education, Sigma Xi, Tau Beta Pi, Theta Chi, and honorary member of Theta Tau and Eta Kappa Nu.

❖

J. P. Gordon

James P. Gordon was born in New York, N. Y., on March 20, 1928. He received the B.S. degree in physics from M.I.T., Cambridge, Mass., in 1949, and the M.A. and Ph.D. degrees in 1951 and 1955 from Columbia University, New York, N. Y. His doctoral dissertation at Columbia University resulted in the first ammonia maser.

Since joining Bell Telephone Laboratories, Inc., Murray Hill, N. J., in 1955, he has continued his work on masers and is now directing a group which is investigating a number of problems relating to this field.

Dr. Gordon is a member of the American Physical Society and Sigma Xi.

❖

G. N. Hatsopoulos

George N. Hatsopoulos was born in Athens, Greece, on January 7, 1927. He attended Athens Polytechnic, School of Mechanical and Electrical Engineering. He received the B.S. and M.S. degrees in 1950, the M.E. degree in 1954, and the Sc.D. degree in 1952 all in mechanical engineering from Massachusetts Institute of Technology, Cambridge, Mass.

He was a research assistant at M.I.T. from 1950–1951, chief engineer at the Matrad Corporation, New York, N. Y. from 1952–1953, teaching assistant at M.I.T. from 1953–1954, consultant at the Matrad Corporation and instructor in mechanical engineering at M.I.T. from 1954–1956, assistant professor in mechanical engineering at M.I.T., and a consultant with Foster Miller Associates, Watertown, Mass., Thermo Electron Engineering Corporation, Belmont, Mass., and Joseph Kaye and Company, Brookline, Mass., during 1956 to 1957.

He directed the research of M.I.T. projects concerned with isothermal surface investigation, the basic development of the thermoelectron engine, and the effects of forced vibrations of heat transfer in free convection. He is co-holder with J. Kaye of three U. S. patents.

Since January, 1958 he has been president of the Thermo Electron Engineering Corporation, Cambridge, Mass.

Dr. Hatsopoulos was a member of the Honors Group in Mechanical Engineering from 1948 to 1950 and is a member of Sigma Xi.

❖

Joseph Kaye was born in Malden, Mass., on November 16, 1912. In 1934, he obtained the S.B. degree in physical chemistry from Massachusetts Institute of Technology, Cambridge, Mass., and was awarded the first Stratton Prize. In 1936, he received a fellowship from M.I.T.; in 1937 he was conferred the Ph.D. degree in physical chemistry, and from 1937–1939 he was a Little Post-Doctorate Fellow. From 1939–1955, he served as a research engineer, an instructor, and an associate professor in the Mechanical Engineering Department of M.I.T. Since 1952, he has been director of the Research Laboratory of Heat Transfer in Electronics, and in 1955, he became a professor in the Mechanical Engineering Department.

J. Kaye

Dr. Kaye, a registered professional engineer in the State of Massachusetts, is a member of the American Chemical Society, American Physical Society, American Society of Mechanical Engineers, American Society for Engineering Education, Institute of Aeronautical Sciences, Sigma Xi, and Pi Tau Sigma, and a Fellow of the American Academy of Arts and Sciences.

◆

John D. Kraus (A'32–M'43–SM'43–F'54), for a photograph and biography, please see page 369 of the January, 1958 issue of PROCEEDINGS.

◆

H. E. J. Neugebauer was born on May 8, 1905 in Berlin, Germany. He studied mathematics and physics at the University of Berlin from 1924 to 1929. In 1935, he received the Doctor's degree from the Technische Hochschule of Dresden with a dissertation on multicolor printing. Until 1951 he worked on various research and development projects, most of which were connected with optics or colorimetry.

H. Neugebauer

Dr. Neugebauer came to Montreal Can., in 1951 and applied his experience in the field of visible light to the study of microwave optics and electromagnetic wave theory. He worked for Eaton Electronics Research Institute of McGill University, Adalia Ltd., and recently for RCA Victor in Montreal, as head of the Wave Propagation Section of the Research Laboratories. He is presently a consultant to RCA Victor, among others.

He is a member of the Optical Society of America, and the Technical Association of the Graphic Arts. He has published a number of papers on optics, colorimetry, and electromagnetic wave theory. At the past International Assembly of URSI in Boulder, Colo., he was elected a member of Commission VI.

George L. Turin (M'56) was born in New York, N. Y. on January 27, 1930. He received the S.B. and S.M. degrees from the Massachusetts Institute of Technology, Cambridge, Mass. in 1952 after completing the cooperative course in electrical engineering in conjunction with Philco Corporation. In the summer of 1952 he was an M.I.T. Overseas Fellow at Marconi's Wireless Telegraph Co. in England. From 1952–1956 he worked at M.I.T.'s Lincoln Laboratory, Lexington, Mass., in the field of statistical communication theory, first as a staff member, and later as a research assistant while completing his doctoral studies. During this latter period he was also a consultant to the firm of Edgerton, Germeshausen, and Grier. He received the Sc.D. degree in electrical engineering from M.I.T. in 1956.

G. L. Turin

Since July, 1956 Dr. Turin has been engaged in communication and radar research studies at Hughes Aircraft Company, Culver City, Calif. He also has taught part-time at the University of Southern California, Los Angeles.

Dr. Turin is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

◆

Harold A. Wheeler (A'27–M'28–F'35) was born in St. Paul, Minn., on May 10, 1903. He received the B.S. degree in physics from George Washington University, Washington, D. C., in 1925 and did postgraduate studies in physics at The Johns Hopkins University, Baltimore, Md., until 1928.

H. A. Wheeler

He was employed by the Hazeltine Corp. from 1924 to 1945, advancing to vice-president and chief consulting engineer. Since 1946, he has engaged in independent work as a consulting radio physicist, and since 1947, his principal occupation has been as President of Wheeler Laboratories, Inc. In this capacity, he is directing the Great Neck and Smithtown laboratories, specializing in microwaves and antennas.

His specialization in antennas dates back to "all-wave" antennas for broadcast receivers around 1935, then radar beacon and IFF antennas during World War II, for which he received the Navy Certificate of Commendation. He has published basic studies of "small" antennas and "large" arrays and has directed recent developments in radar antennas for guiding missiles.

Mr. Wheeler has served IRE in such positions as Director (1934, 1940–1945), chairman of the Standards Committee, and chairman of the Long Island Section. He received the Morris N. Liebman Memorial Prize in 1940 for work on some problems of television. He is a Fellow of the AIEE and Radio Club of America, Associate Member of IEE, and member of Sigma Xi and Tau Beta Pi.

◆

Lowell D. White (M'57) was born in New York, N. Y., on April 18, 1925. He received the A.B. degree in 1949, the M.A. degree in 1951, and the Ph.D. degree in 1956, all in physics from Princeton University, Princeton, N. J. From 1951 to 1953, he was an AEC Predoctoral Fellow and from 1953 to 1955, an instructor.

L. D. White

Since joining the Bell Telephone Laboratories, Inc., Murray Hill, N. J., in 1955, he has worked on noise in traveling-wave tubes, electron beams, and the ammonia maser.

Dr. White is a member of the American Physical Society and Sigma Xi.

◆

Ming S. Wong (S'39–A'42–SM'53) was born in China in 1914. He received the B.S. degree in communication from the University of California, Berkeley, Calif. in 1938 and the M.S. degree in the same field from Iowa State College, Ames, Iowa in 1939.

M. S. Wong

From 1941 to 1958 he was with the Wright Air Development Center, Dayton, Ohio, working on antenna and microwave measurements and later, on propagation. He is now on the staff of the Propagation Laboratory, Air Force Cambridge Research Center, Bedford, Mass.

Mr. Wong is a member of Pi Mu Epsilon, American Physical Society, and Commission II of URSI.

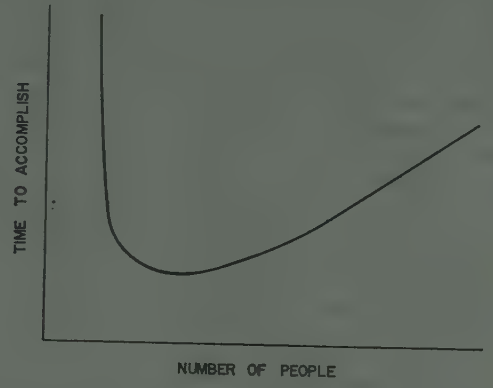
Scanning the TRANSACTIONS

Communications engineering is undergoing a change that is probably as radical as that in any field in radio-electronics. The significance of the changes is attested to by the simultaneous appearance of guest editorials in two different TRANSACTIONS. The change, surprisingly enough, is due largely to developments in another field—digital computers. Although coded transmissions have a long history, the recent advent of high-speed data processing systems is now making it technically feasible to interconnect and coordinate countless complex activities at widely separated locations, using digital transmissions and data handling techniques. So vast are the potentialities that it is predicted that in a relatively few years there will be more communication traffic between digital machines than between humans.

This new field of digital communication is bringing with it totally new problems in communication system design. The major concern of the communications engineer will now be how to transmit digital information as accurately and efficiently as possible. Information theory tells us that low probabilities of error can be achieved either by making the channel capacity much larger than the rate of transmission of information or by increasing the size of the "packages" of information that are encoded for transmission as single units. Unfortunately, the latter alternative increases the complexity of the decoding equipment to a point where it is not presently practicable. Thus we presently can obtain an acceptable probability of error only at the expense of channel capacity. The challenge of the future lies in developing improved techniques and machines which will provide more sophisticated, and at the same time, economically feasible decoding operations. The solution of this key problem will ead to a great saving of channel capacity. Along with improved decoding apparatus will come major improvements in error-detecting and error-deletion coding techniques with a corresponding improvement in accuracy. It is likely that out of this work will come a much closer alliance, if not an actual merger of the fields of information processing and information ransmission. (R. M. Fano, "The challenge of digital communication," IRE TRANS. ON INFORMATION THEORY, June, 1958. J. Z. Millar, "Search for accuracy in communications," IRE TRANS. ON COMMUNICATIONS SYSTEMS, June, 1958.)

The specter of engineering shortages, whether real or maginary, has provoked a great deal of discussion on the raining and utilization of technical manpower. One fact which has emerged from all the talk is that, however great he need for engineers may be, the need for engineering supervisors is greater. It is not enough that a supervisor be a cometent engineer. He must become proficient in the special rocedures and practices necessary to direct the operations f an engineering group, become conversant with and make ood use of the lines of communication within his company, nd most important of all, develop to the fullest his innate alents for leadership. The need for good supervisors is reected in the fact that engineering management has come to he fore as a major field of study. Among IRE's 28 Professional Groups, Engineering Management ranks larger than all but hree. This widespread interest among engineers reflects, oo, the fact that most supervisors come up from the engieering ranks.

To the welter of wails about the manpower shortage, he rebuttal is frequently heard: we need to improve quality more than quantity; or, 50 per cent of what an engineer does ould be done by a technician; or, umpty-ump per cent of ur manpower is wasted in drawing up bids for contracts the ompany never gets; or, somewhat facetiously, why should e match Russia's output, engineer for engineer—we're not going to dance with them. One serious facet of the engineering utilization problem that is all too common is represented qualitatively by the curve below, which says in effect that too many cooks can spoil the broth. If we follow the curve from left to right we see that without a certain minimum number of engineers a project cannot be accomplished at all, that as engineers are added, we rapidly arrive at an optimum number, but that adding still more people will actually make the job longer. The gradual slope of the right end of the curve vs the steep slope of the left suggests that overstaffing is a far more difficult condition to detect than understaffing, and hence apt to be much more common.



Overstaffing usually manifests itself in breaking the job down into too many small pieces. This leads to duplication of effort, poor coordination, and handcuffing the progress of the whole to the speed of the slowest few. Worst of all, the condition is self-perpetuating. As the above curve suggests, an overstaffed organization is likely to miss its project deadlines, and, as a result, add even more personnel to try to make up for it the next time, making matters even worse. Just how serious a situation this is was pointed up by an authority who recently found that if overstaffing is by roughly a factor of three with respect to the optimum number (which appears to be a fairly usual situation) then the time taken to accomplish the job is approximately twice what it would have been with the optimum number. This means that costs are high by a factor of six!

It appears we should take another look at the old grade school problem: "If two men can dig a well in eight hours, how long would it take four men." The answer may be *more* than eight hours because there isn't room in the well for four men. (H. M. Elliott, "The transition from engineer to supervisor," IRE TRANS. ON ENGINEERING MANAGEMENT, June, 1958. R. B. Kershner, "The size of research and engineering teams," *loc. cit.*)

The effects of electric shocks from TV receivers had some light shed on it, at least indirectly, by a recent series of tests on dogs. The dog was selected for the experiments because its response to electric shock is similar to that of man. Dogs were subjected to discharges from capacitors ranging in size from 250 to 3000 $\mu\mu f$, charged to voltages of 1 to 40 kilovolts. None of the discharges produced cardiac arrest, ventricular fibrillation, or any other detectable untoward effect. While it is impossible to predict accurately the human response to similar shocks, it seems probable that the same conclusion applies to adult men. (W. B. Konwenhoven and W. R. Milnor, "The effects of high-voltage, low-capacitance electrical discharges in the dog," IRE TRANS. ON MEDICAL ELECTRONICS, July, 1958.)

In these days of frequency spectrum congestion, there is considerable interest in any new method of compressing the time or frequency band needed to transmit information. A new system, called Ticoss, has been developed which provides a unique approach to multichannel operation. Ticoss stands for Time-Compressed Single-Sideband System. In a typical application ten two-way stations can operate over a single SSB channel by time-sharing multiplex. The multiplexing is accomplished by dividing each half-second into ten time slots. Stations are assigned a given time slot to transmit or receive and then are shut off during the rest of each half-second period to give other stations on other channels their turn. The heart of the system is the time-compression feature. Information to be transmitted is first stored during each preceding half-second and then read out and transmitted at high speed during the assigned time slot. At the receiving end, the compressed message is stored and then read out at its original slower speed, resulting in a continuous message at the receiver output. This novel system is particularly well suited to mobile operations. (M. I. Jacob and J. Mattern, "Time-compressed single-sideband system (Ticoss)," IRE TRANS. ON COMMUNICATIONS SYSTEMS, June, 1958.)

Medical applications of electronic instrumentation and control techniques offer a fertile field of development as broad as medicine itself. An interesting cross section of recent progress in the application of these techniques to studies of the brain, heart, muscles, and blood is presented in the July issue of the IRE TRANSACTIONS ON MEDICAL ELECTRONICS. The issue shows electronics in the following varied roles: detection of minute electrical responses of the brain to specific stimuli in the presence of high background noise by means of sampling, storage and averaging techniques; measurement of oxygen saturation of blood within the body; artificial respiration; measurement of the electrical activity of muscles; heart beat simulator for demonstrating electrocardiographic equipment; and a heart rate counter that gives a direct reading in beats per minute.

Nonlinear systems, in a sense, are several dimensions removed from linear systems and they become more difficult to design and to understand. The nature of the input signals and the mode of operation affect system performance in a manner that is not easily predicted with direct mathematical analyses. However, nonlinearities are always present in control systems whether intentional or not, and efforts to provide a better understanding of nonlinear system operation have been made since the origin of automatic control.

In future control systems the effects of nonlinearities will become more important, and the solution of the associated problems will be of increasing interest. To assess some of the progress that has been attained in this field and to define some of the obstacles that prevent more rapid advances, the PGAC sponsored a Symposium on Nonlinear Control in San Francisco at the Mark Hopkins Hotel on August 19, 1957. The Symposium was divided into two parts: the morning session devoted to "Practical Applications in Nonlinear Control," consisting of three invited papers, and the afternoon session, a panel discussion on the "Obstacles to Progress in Nonlinear Control."

The symposium aroused considerable interest in the papers and the panel discussions and, fortunately, all of the recorded panel discussions and the papers for the morning sessions were procured. They are now available in a special TRANSACTIONS of the Professional Group on Automatic Control issued in June.

Books

Mass Spectroscopy by H. E. Duckworth

Published (1958) by Cambridge University Press, 32 E. 57 St., N. Y. 22, N. Y. 175 pages+17 bibliography pages+7 appendix pages+6 index pages+xii pages. 41 figures. 8½×5½. $6.50.

Professor Duckworth's monograph covers the mass spectroscopy field from the viewpoint of a physicist, but in an apparent effort to keep it brief he has neglected some areas and has repeated what has been said in other books on the subject. As the author's preface says, the monograph is concerned with the operation and application of mass spectroscopy and mere mention is made of chemical reaction rates and mechanisms while electronic or high vacuum techniques are not included at all. The book has an excellent chapter on the role of mass spectroscopy in nuclear physics research.

Physicists in today's environment should have such a handy, up-to-date reference to mass spectroscopy, but the electronics engineers or chemists might do better to find books more closely akin to their needs.

The most outstanding merit of the book lies in its up-to-date bibliography and its treatment of atomic masses and nuclear physics. The most serious deficiency lies in the fact that it has not said much that has not been said in other books on the subject. In fact Barnard's book (1953) has covered the same topics and included information useful to a much wider spectrum of technical people.

On the whole the book is very interesting and worthwhile and would make good reading for all scientific people. The book is certainly the most recent one published and if one required a general reference book on mass spectroscopy this book would adequately fill that need.

HAROLD C. MATTRAW
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Introduction to Electromagnetic Engineering by R. F. Harrington

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 291 pages+12 appendix pages+1 bibliography page+6 index pages+xii pages. Illus. 9¼×6¼. $8.00.

Professor Harrington has written a very attractive book. It contains a thorough and well-organized introduction to electric and magnetic field problems, with the emphasis on the static case. He has directed it towards engineering students at the junior, senior, and first-year graduate levels. Calculus and some circuit theory are presupposed.

Unlike most books on electromagnetic theory, this one makes use of the experimental results of circuit theory as a starting point for the field theory. In this way, continuity with the student's previous work is emphasized. Thus Kirchhoff's voltage law is generalized to include the induced voltage due to changing magnetic flux, while the current law is generalized by adding a term in the rate of change of charge accumulated at a junction. These two relations lead to Maxwell's equations quite conveniently. In the earlier part of the book, it seems that this approach to some extent sacrifices physical insight in favor of mathematical convenience. However, in the later applications of Maxwell's equations to static problems, the missing relations show up, and so do the physical meanings.

Vector analysis is adroitly introduced in the second chapter, and is used fully throughout the rest of the book. In the third chapter, electric field intensity is introduced as a quantity whose line integral equals voltage. In a similar emphasis on the circuit viewpoint, magnetic flux density is defined as a vector field having a surface integral related to the induction of voltage in a loop. In the fourth chapter, *D* is introduced as vector field having divergence equal to charge, while *H* is essentially defined by the Maxwell-Ampere equation. The possibility that *B* and *H*, *E* and *D* might be related in some way is explored by reference to ideal inductors and capacitors. In Chapter Five, electrostatics is treated as a special case of Maxwell's equations. The fields resulting from point charges, line charges, and dipoles are considered, as is reciprocity, and Gauss's law. In Chapter Six the field of steady electric currents is considered. Starting with the magnetic vector potential, the Biot-Savart law is derived. The fields of various one and two-dimensional current distributions are considered, including loops, quadripoles, and solenoids. In Chapter Seven, the specification of a vector function in terms of flow and vortex sources is used to introduce the ideas of electric and magnetic polarization. Use is made of the concept of magnetic charge and magnetic current in stressing the duality between electric and magnetic field problems. In Chapter Eight consideration is given to boundary problems. Among the examples given are concentric spheres with two conducting media, a current-carrying wire in a magnetic sheath, images for a pair of conducting spheres, and a disk of constant potential in a plane of zero potential. Again, emphasis is placed on the duality of electric and magnetic problems. In Chapter Nine circuit elements are considered, including resistive, capacitive, and inductive systems. The coefficients of potential, capacitance, electrostatic induction, resistance, and conductance are clearly treated, together with methods of finding the values of circuit elements. Methods for finding upper and lower limits of approximation are included. Finally, in Chapter Ten, the electromagnetic field is dealt with. Starting with Maxwell's equations for a nonconducting medium, the wave equation is derived. The properties of plane wave solutions and of standing waves are then found. The idea of generalized current is used to generalize Maxwell's equations to conducting media. Poynting's theorem is followed by discussion of the electromagnetic potentials, and radiation. A short section on waveguides and resonant cavities closes the book.

A dominant feature of the text is the quality of the writing. Ideas are clearly stated, and care is evident in the continuity from paragraph to paragraph, chapter to chapter. Problems and review questions are included. All in all, it is a good book, and should be teachable as well.

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Transients in Electrical Circuits by G. V. Lago and D. L. Waidelich

Published (1958) by The Ronald Press Co., 15 E. 26 St., N. Y. 10, N. Y. 382 pages+7 appendix pages +3 index pages+vii pages. Illus. 9¼×6¼. $7.50.

This book is intended as a textbook for the electrical engineering student in his junior or senior year. The only mathematical background required is a standard course in differential and integral calculus. A first course in electrical circuit theory covering Thevenin's and Norton's theorem is assumed. The growing emphasis on pulse type of circuitry and the solution of the associated transient problems by means of the Laplace transform is reflected in this book. In the first chapter trivial problems involving constant current or constant voltage sources feeding single circuit elements are presented to develop the concept of duality between currents in one form of circuit and voltages in its complement. This duality concept is continued more or less throughout the entire book. In the second chapter, complex circuits having one storage element are solved for their transient behavior by classical means using the separation of variables. In the third and fourth chapter, a simple treatment of second-order differential equations and hyperbolic function is presented with some applications to circuits having two storage elements. With the first third of the book as a background, the Laplace transform method is presented in Chapter 5 without proofs. The lack of mathematical rigor to prove the validity of the Laplace transform method in a book of this type is entirely proper. The average undergraduate student needs this method as a tool early in his training and can study the mathematical proofs in a later mathematics course. A short illustrative Laplace transform table is given in this chapter with a more complete table in the appendix. Simple problems are solved in Chapter 5 by the Laplace transform method and the results compared with the differential equation solutions of Chapters 3 and 4. Factoring of higher degree polynomials is discussed in Chapter 6 and treatment of more complicated inductive circuits having mutual inductance between coils is explained in Chapter 7 using the factoring methods of Chapter 6. Chapter 8 deals with transients in circuits having ac rather than dc sources while Chapter 9 considers sources having other than sinusoidal waveforms. Chapters 10 and 11 deal with steady-state responses to sinusoidal and nonsinusoidal waves, respectively. Chapters 12 and 13 deal with mechanical systems and servomechanisms. The remaining three chapters, comprising 10 per cent of the book, deal with the Fourier series, the Fourier integral, and some applications of each.

This appears to be an excellent undergraduate textbook. It is well written, with many interesting and practical problems as examples and exercises. Its organization is such that the graduate engineer not versed in the Laplace transform method could easily use this book as a self-study guide although the lack of problem solutions might be a handicap. It is certainly a good book for an organized course on transients and even students in their junior year should find it easy reading.

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Modern Computing Methods

Published (1958) by Philosophical Library, Inc., 15 E. 40 St., N. Y. 16, N. Y. 103 pages+11 bibliography pages+14 appendix pages+vi pages. Illus. 9¼×6. $8.75.

This small but rather high-priced book has been developed from a series of lectures delivered by staff members of the Mathematics Division of the British National Physical Laboratory to representatives of industrial firms. The course of lectures was organized by the Electrical Engineering Department of the Imperial College of Science and Technology.

A condensed guide is presented for numerical methods which are useful in problem-solving, both methods intended for the hand computer using a desk machine, and methods applicable to the solution of problems by high-speed digital computing equipment.

The first four chapters are concerned with the solution of algebraic problems, while Chapters 5 through 9 discuss methods derived from analysis. Relaxation methods are described in Chapter 10, Chapter 11 discusses the problems arising in the construction of mathematical tables, and the final chapter illustrates the need for using a variety of techniques in the course of solving a given problem.

Three appendixes offer an extensive bibliography, an example of the use of a high-speed digital machine in the solution of a set of nonlinear simultaneous differential equations, and an account of the principles and manner of working of a mechanical differential analyzer.

In view of the large and growing importance of machine computation, the present little volume is most welcome as an introduction and guide to the field. The anonymous authors are to be congratulated on the scope of the ideas they have set down so succinctly.

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Einführung in die Mikrowellen-Elektronik Teil II: Lauffeldröhren by Werner Kleen and Klaus Pöschl

Published (1958) by S. Hirzel Verlag, Stuttgart, N., Birkenwaldstrasse 185, Germany. 171 pages+16 appendix pages+5 index pages+x pages. Illus. 9¼×6¼. DM 28.

This textbook on traveling-wave tubes is the second volume of a series on "Introduction to Microwave Technique." Since the first volume ("Fundamentals") is not available in this country, some of the derivations referred to in the present text must be taken on faith.

However, this is no serious defect because the literature is extensively quoted and equations related to amplification, bandwidth, maximum power output, and other pertinent tube characteristics are generally derived in this text, either in the form given by the originators or modified by the authors who are active contributors to the art.

Both authors are professors at the Munich Institute of Technology and consultants for the Siemens & Halske A. G., one of the largest West German firms in the electrical and machine industry.

The book is very thorough and, in spite of its relatively short length, conveys a good understanding of all important features.

The major part is devoted to the normal forward wave tubes and treats linear theory, noise, nonlinearities, and practical designs. Separate chapters are devoted to backward wave amplifiers and oscillators, to multiple stream tubes, to tubes that use resistive surfaces as retarding lines, and to transverse field tubes.

Related devices are discussed such as traveling-wave oscillographs and devices utilizing the Çerenkov effect. The number of literature references from American as well as European sources is impressive. Conveniently, each chapter has a separate list of references which are well cross indexed according to authors and subjects.

The only minor objection of this reviewer refers to the choice and incomplete list of symbols, and of their dimensions. It is understandable that in quoting diversified original contributions, the first authors' choice of symbols is respected but this leads to inconsistencies in a textbook, and one symbol is occasionally used for two different things, such as k for Boltzmann's constant and for ω/c.

However, these are minor defects. The authors are to be commended for a very readable text that brings students and engineers not intimately connected with tube design up to date, insofar as this is possible in an art that is still in a state of rapid flux and growth.

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Principles of Electricity (3rd ed.) by Leigh Page and N. I. Adams, Jr.

Published (1958) by D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N. J. 524 pages+9 index pages+xiii pages. 323 figures. 9¼×6¼. $7.50.

This third edition of one of the best-known intermediate level E & M textbooks will be welcomed by many of us as an old friend in new dress. It differs from the second (1949) edition in the use of mks units, and in modernization of subject matter. The latter consists of certain additions and deletions; the basic viewpoint and manner of development remains the "traditional" one. Thus the field vector H is defined, on page 103, in terms of the force on a unit pole, while B is not defined until page 118, as a derived quantity associated with the state of matter. The force law $F=I\times B$ is developed gradually, and does not appear in full generality until page 233.

In view of the fact that this procedure will inevitably be criticized as old-fashioned, if not downright illogical, this reviewer would like to say something in its defense. A few years ago there was a great deal of talk to the effect that B is in some sense a more "fundamental" quantity than H, the former being the basic force vector, *defined* by the equation $F=I\times B$, the latter only a derived quantity associated with the state of matter; this is the viewpoint adopted in most recent textbooks. I have never been able to understand its alleged advantages. On the contrary, a teacher who attempts to build up an analogy between E and B on one hand, D and H on the other, will then be faced with the very difficult problem of explaining why it is that E and H satisfy the same boundary conditions at the interface of two media, why it is that easily polarizable substances are those which have large ratios D/E and B/H, *not* H/B; and later on, why it is that E and H, *not* E and B, occupy corresponding positions in Maxwell's equations. The simple fact is, of course, that E, H, D, and B are *all* force vectors, in appropriately defined experiments, and E and H are force vectors in *similar* experiments. The macroscopic vectors are, furthermore, all associated with the state of matter, their differences corresponding to different kinds of averages over the microscopic (intermolecular) fields.

From the standpoint of logical development, the method of Page and Adams has the advantage of not obscuring the basic symmetry of electromagnetic theory, a symmetry which is very helpful to the student learning the subject.

Of course, in intermediate-level instruction questions of logical development are not of primary importance; most students at this stage have little appreciation of the distinction between an axiom, a definition, a convention, a theorem, and an experimental fact, and tend to dismiss as pedantic hair-splitting any attempt to point them out. So let us look at the question from the standpoint of pedagogy. I take it as axiomatic that the best way of teaching a subject is the one which builds most directly on what is already familiar to the student, and for obvious reasons this is likely to be the historical line of development. Now, every child is familiar with the fact that magnets exert forces on each other, which decrease with increasing separation; by using this in the definition of H we are merely giving quantitative expression to a qualitative fact which he learned in playing with his toys. But I suspect that there are many competent electronics technicians and radio repairmen who do not know that a magnetic field exerts a force on a current, and to whom the mathematics of a vector cross product would make B seem hopelessly abstract. Thus, also from the standpoint of pedagogy I think that the "old-fashioned" approach of Page and Adams is superior to its modern variants.

For the student who is mature enough to see that the most logical development is the one which requires the minimum of assumptions and appeal to experiment, one can do no better than to show him the masterful treatment in Page and Adams' advanced work, "Electrodynamics" (Van Nostrand, 1940). From it this reviewer learned for the first time how much of formal electromagnetic theory is determined already by the definition of E and the principle of relativity; and indeed, how much of what we usually call physics is really nothing but applied geometry. We may note also that viewpoints which seemed old-fashioned two years ago may turn out to look very modern in the near future. Page and Adams give a very interesting discussion of the symmetry of electromagnetic theory under the transformations $H'=H\cos\theta+E\sin\theta$, $E'=E\cos\theta-H\sin\theta$. For many years, theoretical physicists would have rejected this on the grounds that the sum of a polar vector and an axial vector is as devoid of physical meaning as an expression which is not dimensionally homogeneous. But with the recent discovery of parity nonconservation, we have learned that nature *does* have a built-in distinction between right-handed and left-handed coordinate systems; the simplest of all relativistic wave equations, discovered by H. Weyl in 1929, necessarily requires this. Within the past year, the above transformation has begun to appear in the literature of theoretical physics, where it turns out to have an intimate connection with neutrino theory. I will venture the prediction that ten years from now, it will be universally recognized as one of the most important basic properties of the electromagnetic field.

"Principles of Electricity" provides a very detailed account of the theory of electrical measurements, another topic which seems to have been deemphasized in recent years to the detriment of education. For several years I have been concerned about the fact that universities are now turning out Ph.D. experimental physicists and electrical engineers who use voltmeters daily, but do not know what is inside them, cannot explain the principles of the d'Arsonval movement, and have no conception of the ultimate source of calibration of their measurement devices. For this reason alone, one would have to recommend the book very highly.

After all this praise, one should try to strike a balance by finding something to criticize. The treatment of dielectrics, particularly Section 17, which considers the internal field and leads to the Clausius-Mosotti formula, is quite oversimplified, a defect which seems to be universal in textbooks.

There is by now a voluminous literature dealing with the shortcomings of this treatment, and attempting to improve on it. The Clausius-Mosotti formula is never verified accurately in experiments, and often it is such a poor representation of the facts as to be worse than useless. A student will gain a false impression of its validity unless this is pointed out.

In conclusion, the appearance of this new edition could not have come at a more appropriate time. In a year which is seeing the whole philosophy of American education subjected to careful reexamination, a book which maintains the traditional standards of completeness in subject matter, seeking no short-cuts, must be recommended for serious consideration to every teacher of intermediate-level electricity and magnetism.

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Abstracts of IRE TRANSACTIONS

The following issues of TRANSACTIONS have recently been published, and are now available from the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, N. Y. at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

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Automatic Control

PGAC-5, JUNE, 1958

Special Symposium Issue, The Editor (p. 41)

The Issue in Brief (p. 42)

Part I: Practical Applications in Nonlinear Control

The Design and Performance of a Model, Second-Order, Nonlinear Servomechanism—R. E. Kuba and L. F. Kazda (p. 43)

This paper discusses the design and performance characteristics of a model, second-order, nonlinear servomechanism. The design procedure stems from principles laid down in the authors' previous paper, in which the nonlinear differential equation characterizing this servo was synthesized. The physical aspects of the various building blocks needed for nonlinear servo construction are considered. Schemes for generating nonlinear functions are described, along with methods for accomplishing the multiplication and differentiation of the control system's variables. Schematic diagrams of the nonlinear servo are presented, in addition to instructions for adjusting the parameters to obtain the proper response behavior. The results of a comparison of equivalent nonlinear and linear servo operation are given in the form of photographs illustrating the control system's error response for various magnitudes of step inputs of position. The nonlinear system's error response is shown to be superior to the linear system's error response in that the nonlinear response exhibits no overshoot and reduces the system error to zero in approximately the time required for the linear system's error response to pass through zero for the first time. The response time of the nonlinear, model servo corresponds closely to the predicted response time.

The Practical Realization of Final-Value Systems with Limiting Constraints—R. C. Booton, Jr. and A. Rosenbloom (p. 49)

In certain applications, the desired function of a control system is to control some variable accurately only at one instant of time. Examples of this can be found in homing missile guidance systems or aircraft landing systems. In the latter case, it is desired to have the vertical component of velocity be small at the instant of touchdown. Complicating features of such systems are the constraints imposed by physical limitations, such as the limited vertical acceleration capability of airplanes, and the noise or inaccuracy of measurements of the controlled variable. The optimum configuration for such systems has been derived, and this form can be used as the basis for the design of actual systems. The theoretical derivation of the optimum system idealized the actual situation, and a number of problems must be considered when the physical system is designed. Such problems as the closed-loop realization, the number of measurements of the system response, and the manner in which these measurements are utilized are discussed in this paper.

Combined Hysteresis and Nonlinear Gains in Complex Control Systems—R. V. Halstenberg (p. 51)

The types and sources of hysteresis commonly found in mechanical systems, and some of the effects thereof, are discussed.

The describing function technique as specifically applied to studying hysteresis-caused limit cycles is outlined.

The use of an analog computer for studying hysteresis in servosystems is reviewed.

Techniques are presented for determining active and passive compensation to eliminate or reduce hysteresis limit cycles.

Finally, a method is given for analyzing hysteresis plus a single-valued nonlinearity when they occur together or apart in a single or multiloop control system. By this method it is possible to synthesize a nonlinear gain characteristic which eliminates or reduces a hysteresis limit cycle. The validity of the method is demonstrated by comparison with analog computer results.

Part II: Obstacles to Progress in Nonlinear Control

Introduction—Harold Chestnut (p. 59)

Availability of Necessary Theory for the Analysis and Design of Nonlinear Systems—O. J. M. Smith (p. 60)

Nonlinearities in Machine Tools and Missiles—John L. Bower (p. 62)

Nonlinearity in Process Systems—Ernest G. Holzmann (p. 63)

The Role of Computers in Analysis and Design of Control Systems—George P. West (p. 65)

Problems of Nonlinearity in Adaptive or Self-Optimizing Systems—Charles F. Taylor (p. 66)

Open Panel Discussion (p. 67)

Closing Remarks (p. 70)

Committee for the 1957 PGAC Symposium on Nonlinear Control (p. 73)

Book Review (p. 74)

PGAC News (p. 75)

Broadcast Transmission Systems

PGBTS-10, JUNE, 1958

Announcements (p. 1)

Cochannel Television Interference and its Reduction—E. W. Chapin, L. C. Middlekamp, and W. K. Roberts (p. 3)

The undesired effects of cochannel television interference vary both with the intensity and the frequency of the interfering signal. It is found that there are three types of frequency-variation of objectionability, namely: 1) A progressive decrease of objectionability as the frequency of the undesired signal is shifted away from the carrier frequency of the desired signal, which we have called the Beat Size Effect; 2) superimposed on the Beat Size Effect there is a cyclic variation in objectionability which repeats at intervals corresponding to the horizontal scanning frequency; and 3) superimposed on each of these variations there is a "fine-grain" cyclic variation which repeats at intervals corresponding to the vertical scanning frequency. We have called the cyclic variation 2) and 3) Beat Pattern Effects. Advantage may be taken of the Beat Size Effect and the Beat Pattern Effects to reduce cochannel television interference by appropriate specification of the operating frequencies and frequency tolerances of the desired and undesired stations. It is shown that it is also possible to reduce the objectionable effects of cochannel television interference by the use of certain postdetection devices in the television receiver. Narrow-band video filters, high-pass video filters, and diode clamp video correction circuits have given pomising results.

IRE Professional Group on Broadcast Transmission Systems Membership Directory (as of February 28, 1958) (p. 25)

Communications Systems

VOL. CS-6, NO. 1, JUNE, 1958

Search for Accuracy in Communications (Guest Editorial)—J. Z. Millar (p. 1)

Time-Compressed Single-Sideband System (Ticoss)—M. I. Jacob and J. Mattern (p. 2)

This paper describes a time-compressed single-sideband system (Ticoss), which, by use of time-sharing techniques, avoids many of the problems of a frequency-multiplexed system of the same capacity. Included in the discussion is a description of compressor-expander units for both voice and digital data systems.

Evaluation of IF and Baseband Diversity Combining Receivers—R. T. Adams and B. M. Mindes (p. 8)

Techniques of diversity reception have advanced rapidly with the advent of over-the-horizon communication. Because of the rapidly fluctuating signals encountered in tropospheric scatter propagation, strong-signal selection (switching diversity) has been largely supplanted by more sophisticated signal-combining techniques. Present tropospheric scatter systems commonly employ either postdetection ratio-squared combining, or more recently, a technique of predetection linear addition. A theoretical and experimental study comparing these two methods is the subject of this paper. Apart from obvious advantages of simplicity, the predetection technique exhibits lower distortion under multipath conditions, due to the linear combining process.

Choosing the Optimum Type of Modulation—A Comparison of Several Communication Systems—George J. Kelley (p. 14)

The engineer designing a new communications system often has available a choice between several different types of RF modulation. The four main methods considered here are standard amplitude (AM), double-sideband suppressed-carrier (DSBSC), single-sideband (SSB), and frequency modulations (FM). Some of their basic system performance characteristics are evaluated on a comparative basis for the transmission of voice and pulsed data. Factors considered include: compatibility, effective range, bandwidth, signal-to-noise performance, interference rejection capabilities, distortion characteristics, required stability, required transmitter power, and resulting circuit complexity.

The choice of the best type of modulation for a particular communications system requires the simultaneous consideration of many such factors evaluated for the basic requirements of that system. Because these factors vary with system parameters and because they may be of differing relative importance, it is not possible to say that any one type of modulation is best for all uses. The practical manner in which the choice may be made is illustrated by examples drawn from several types of communication systems.

Reliability and Economics of Telecommunication Systems—Z. Prihar (p. 22)

The paper evaluates telecommunication system functional reliability, based on average failure rates, and formulates operational reliability that also takes into consideration the duration of breakdowns and the time necessary for their repair. Various system arrangements are considered. Optimum maintenance methods are determined from operational reliability and, using the inventory method, expected revenue losses are formulated for the different systems.

Communication in Air-Traffic Control—Robert M. Stuckelman (p. 27)

One of the major obstacles to the solution of the air-traffic control problem is the limitation imposed on information flow by the outdated air-to-ground communication system now in use. A study of the present system and its deficiencies gives a set of requirements for a communication system that will assist materially in the solution of the air-traffic control problem. Another set of communication system requirements is obtained by analysis of the characteristics of the future air-traffic-control system. The composite of these two classes of requirements can be satisfied to a large extent by many communication techniques presently available. The problem of determining an optimum air-traffic-control communication system is now in the process of being solved. This system will be called the Air-Traffic-Control Signaling System.

Contributors (p. 30)

Engineering Management

Vol. EM-5, June, 1958

The Transition from Engineer to Supervisor—Herbert M. Elliott (p. 29)

In a rapidly expanding engineering organization the need for first-line supervision is as critical, if not more so, as for working engineers. For the development of a stable organization, this supervision must come from the ranks of the engineering force.

The training of an engineer for supervision must, of necessity, be on-the-job training. This is usually a long and sometimes delicate process. The problems that arise fall into two main categories.

The first category involves the specific techniques of administration—preparation of budgets, merit-increase policy, service reviews, and general organization. The second category involves the specific techniques of project control—determination of engineering schedules, coordination of the activities of a group of engineers, and the problem of communications between groups.

The new supervisor must not only be educated in these areas, but he must also be helped in making the transition to supervision. Problems arise in maintaining an effective working relationship with people who may now be working for him rather than with him. The new supervisor also has a personal problem of reorienting himself, of seeing the company organization in a different light.

The intent of this paper is to discuss these problems and the methods used to guide engineers through this transition period in a rapidly expanding engineering department of RCA.

Organizing for Management Controls—J. B. Lewi and S. J. Ross (p. 32)

A plan for establishing management controls is presented which uses the basic management control principles of organizing, planning, executing, and follow-up. The particular experience of our company is cited whereby the assignment was given to staff personnel who had the requisite experience and company service.

Each of the steps in the control process is explained, with emphasis on the follow-up activity which makes possible the continuing acceptance and usefulness of the established controls. The importance of building an overall operational system is also discussed.

The Size of Research and Engineering Teams—R. B. Kershner (p. 35)

This paper discusses the very common problem of overstaffing in a large development engineering effort. A number of the technical, organizational, and psychological problems that lead to inefficiency in the engineering effort are discussed. It is shown that because of this variation of efficiency with size, the "usual" man-hour estimate may be meaningless. In fact, it is asserted that an increase in staff may actually lead to an increase in total time for accomplishing a development engineering effort. Finally, it is pointed out that the usual mechanisms for estimating efforts of new assignments may automatically perpetuate or even intensify an overstaffing problem.

Management of a Navy R and D Activity—Rear Adm. Seldon B. Spangler (p. 39)

The philosophy of management of a Navy Bureau of Aeronautics Research and Development activity is described and compared with similar large size industrial activities. Complications arise in execution because of the external influence of a Civil Service, which has not been adapted to technological growth. The impact of staff organization, both in the Navy and the Secretary of Defense, is similar to the situation in huge centralized corporations. Military control is not considered to be a problem.

The efforts of a military laboratory must be aimed at improving the capabilities of its parent service to wage war. This puts the Navy laboratory into the development and applied research field, rather than its basic research. Freedom of investigation is enhanced since development is against a concept and not against a cash balance.

Measuring Engineering Effectiveness—R. C. Langford (p. 45)

The task of measuring engineering effectiveness can be broken down by an analysis of measurement of effectiveness and engineering. These parts are examined from the point of view of top Management, Sales, Manufacturing, Customer, Competitor, Research, and the Engineering Department itself to determine views on the subject of measuring the Engineering Department's effectiveness. Virtually in all departments *time*, *price*, and *quality* are paramount points of interest. These features mean slightly different things in the various departments and a detailed breakdown is given for the Engineering Department itself. Perhaps the major idea postulated is that of meeting a goal by meeting it exactly rather than underrunning or overrunning.

Technical Communications in Defense Industry—F. N. Eddy (p. 49)

Restricting its attention to those non-policy-making technical communications within the defense industry, this paper attempts 1) to show the importance of such communications by means of practical examples, 2) to survey and evaluate current systems employed for both internal and external communications by firms of differing size, and 3) to suggest possible alternative systems for ameliorating extant problems. In particular, it is maintained that within an increasingly competitive environment, it is management's responsibility to foster those systems of communication which minimize losses resulting from the duplication of effort. Possible methods for attaining this end are discussed, resulting in the specific conclusion that a more highly integrated, centrally located group would diminish wasted engineering time by recording all relevant technical information in such a manner that it would be easily accessible to the engineering staff.

Reduction of Inventions to Practice—Albert Woodruff Gray (p. 54)

Inventions to be patentable must be reduced to practice and embodied in some distinct machinery or composition of matter that will work and accomplish its intended purpose. The mental process of the inventor must be complete and brought to a point where invention ceases and construction may begin.

This law does not require that an inventor develop his discovery to the highest degree of perfection, but he must describe his method with sufficient clearness and precision to enable those skilled in the matter to understand what the discovery is and point out a practicable way of putting it into operation.

It is not the object of these laws to grant a monopoly for every trifling device, every shadow of a shade of an idea which would naturally spontaneously occur to any skilled mechanic or operator in the ordinary process of manufacture.

Magazine Review Section (p. 56)

For Your Bookshelf (p. 57)

Information Theory

Vol. IT-4, June, 1958

Frontispiece—Robert M. Fano (p. 62)

The Challenge of Digital Communication—Robert M. Fano (p. 63)

Some Comments on the Detection of Gaussian Signals in Gaussian Noise—D. Slepian (p. 65)

It is pointed out that a frequently used mathematical model of the detection problem yields detection with arbitrarily small probability of error in many cases of engineering interest. Some comments are made as to why the model is inadequate from an engineering standpoint.

A Useful Theorem for Nonlinear Devices Having Gaussian Inputs—Robert Price (p. 69)

If and only if the inputs to a set of nonlinear, zero-memory devices are variates drawn from a Gaussian random process, a useful general relationship may be found between certain input and output statistics of the set. This relationship equates partial derivatives of the (high-order) output correlation coefficient taken with respect to the input correlation coefficients, to the output correlation coefficient of a new set of nonlinear devices bearing a simple derivative relation to the original set. Application is made to the interesting special cases of conventional crosscorrelation and autocorrelation functions, and Bussgang's theorem is easily proved. As examples, the output autocorrelation functions are simply obtained for a hard limiter, linear detector, clipper and smooth limiter.

The Effect of Instantaneous Nonlinear Devices on Cross-Correlation—Roy Leipnik (p. 73)

If $X_1(t)$, $X_2(t)$ are two noises (stochastic processes), f and g are functions describing the action of two instantaneous nonlinear devices, we say that the (m, n) cross-correlation property holds in case the cross-correlation of $f(X_1(t_1))$ with $g(X_2(t_2))$ is proportional to the cross-correlation of $X_1(t_2)$ with $X_2(t_2)$, whenever f and g are polynomials of degrees not exceeding m and n, respectively. We take $m=\infty$ or $n=\infty$ to mean that f or g is any continuous function.

The Barrett-Lampard expansion of the second-order joint density of $X_1(t_1)$ and $X_2(t_2)$ is used to derive an expression for the cross-correlation of $f(X_1(t_1))$ and $g(X_2(t_2))$. This expression yields necessary and sufficient conditions for the validity of the cross-correlation property in three cases: $X_1(t)$ and $X_2(t)$ stationary, m, n unrestricted; $X_1(t)$ stationary, m, n unrestricted; $X_1(t)$ stationary, $n=1$.

Examples are constructed with the help of special orthonormal polynomials illustrating the necessity and sufficiency of the conditions.

Some Properties of Nonbinary Error-Correcting Codes—C. Y. Lee (p. 77)

An error-correcting code may be thought of as a subset S_0 of points belonging to a set S in which a metric is defined such that the distance between every pair of distinct points of S_0 is larger than some given number. In Hamming's original formulation, S was taken to be the set of all 2^n n-bit binary numbers and the distance between a pair of binary numbers s and t was taken to be the number of bits of s which do not agree with the corresponding bits of t. In this note we shall take S to be the set of all n-tuples in which each coordinate of an n-tuple can assume one of k integral values: $0, 1, \cdots, k-1$, with $k \geqq 2$. Properties of these nonbinary codes will be discussed.

The Effect of Noise Upon a Method of Frequency Measurement—T. B. Pickard (p. 83)

The effect of noise upon a method of information transmission and recovery is analyzed. The information is coded as the frequency shift of a carrier. The carrier is assumed to be transmitted over two channels which have 90° phase difference. The recovery of the information is accomplished in a new way by measuring the frequency shift by means of a "coherent cycle counter."

A general expression is obtained for the expected frequency measurement of the coherent cycle counter in terms of the signal and noise autocorrelation functions. The percentage bias of the counter is shown to be a function only of the signal-to-noise ratios in the two channels. In the noise-free case, the expected frequency measurement is given by the centroid of the signal power spectrum. When no signal is present the average indicated frequency is zero, thereby effectively cancelling the average effect of the sources of noise in the system. For applications in which the transmitted frequency fluctuates about the carrier or reference frequency, the method is shown to be superior to both an axis crossing counter and an ideal phase differentiator when it is required to operate through zero frequency difference.

Correspondence (p. 88)

PGIT News (p. 89)

Roster of PGIT Members (p. 91)

Medical Electronics

PGME-11, July, 1958

A Sensitive System for the Measurement of Brain Responses in the Intact Human—John F. Davis (p. 29)

An all-electronic method is described whereby minute electrical responses in brain recordings can be measured reliably even in the presence of large noise-to-signal ratios. The signal in this instance is a discrete response to a controlled stimulus. The "noise" is not white noise in this case, but the normal rhythmic activity of the electroencephalogram (EEG) which is randomly related to the signal. The responses are usually invisible in the EEG recording but they can be detected by means of averaging and storing techniques. The system makes use of gated integrators and floating-grid vacuum-tube voltmeters.

Oximetry—W. Paul (p. 34)

Oximetry is the estimation of per cent oxygen saturation of blood by photometric means. Incident light may be reflected from a vascular bed or cuvette and the reflected light measured, or the transmitted light may be measured to yield the required data. Theoretically, transillumination lends itself to absolute measurement with a two-color system, whereas reflection oximetry requires three colors.

The instrumentation described employs two colors along with an alternating light source to allow ac amplification. An analog computer provides a continuous ratio of the corresponding two currents recorded by an ink-writing milliammeter. The over-all response to a step change has a period of less than 0.5 second and is considered rapid enough for clinical dye curve studies. There is reason to believe that the deficient long-term stability of the photocells limits function as an absolute oximeter.

Further Progress in Electronic Control of Artificial Respiration—L. H. Montgomery and S. E. Stephenson, Jr. (p. 38)

It is the intention of this paper to cover work on the use of electronic amplifiers in conjunction with other instrumentation as supportive devices in cases of partial or complete muscle failure. It is a continuation of work previously published in these Transactions and indicates the trend of further applications of electronic engineering in this field.

The Effects of High-Voltage, Low-Capacitance Electrical Discharges in the Dog—W. B. Kouwenhoven and W. R. Milnor (p. 41)

Reported are the results on animals of 520 discharges from capacitors ranging in size from 250 to 3000 micromicrofarads, charged to voltages of 1 to 40 kilovolts. These discharges were sent through the animals at various instants in the heart cycle, and in most cases the current path was from foreleg to hind leg (analogous to the path from hand to foot). The time constant (RC) of the discharges also was varied by inserting resistances in the discharge circuit.

None of these discharges produced ventricular fibrillation, cardiac arrest, or any other untoward effect which could be detected by the methods used. While it is impossible to accurately predict the human response to similar electric shocks, it seems probable that the same conclusion applies to adult man.

A New Six-Channel Electromyograph for Studies on Muscle—J. V. Basmajian (p. 45)

To study potentials from several different muscles or parts of the same muscle concurrently so that relative activity could be compared directly, a special apparatus has been developed and tested over the past several years and is reported now for the first time.

This apparatus consists essentially of six identical but entirely separate amplifiers, each fitted with a small cathode-ray tube for monitoring. Together with the control unit, they are mounted on the top of a compact metal cabinet. Situated on the floor of the cabinet is the power supply unit next to a light-proof compartment containing six recording cathode-ray tubes. The traces on these tubes are recorded by a 35-mm linagraph camera affixed to the side of the cabinet. This new instrument has been used extensively and with good results in the author's laboratory for a variety of studies on muscle function.

An Electronic Heartbeat Simulator and a Cardiac Tachometer—O. Z. Roy (p. 48)

The procedure for obtaining an artificial heartbeat with the use of multivibrator techniques is described. The chief feature of this design is the use of well-known circuitry to produce: 1) three pulses of variable amplitude and relatively long periods, and 2) variable time delays between the pulses of up to 0.5 second.

Also described is the circuit for a cardiac tachometer with two linear scales, the ranges of which are 0 to 75 and 0 to 180 beats per minute, a response time from zero to full scale (10 seconds), and an accuracy of better than 2 per cent.

* * *

Abstracts and References

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

Acoustics and Audio Frequencies...... 1668
Antennas and Transmission Lines..... 1668
Automatic Computers............... 1669
Circuits and Circuit Elements......... 1669
General Physics.................... 1671
Geophysical and Extraterrestrial Phenomena......................... 1672
Location and Aids to Navigation...... 1674
Materials and Subsidiary Techniques.. 1674
Measurements and Test Gear........ 1677
Other Applications of Radio and Electronics......................... 1678
Propagation of Waves............... 1678
Reception......................... 1679
Stations and Communication Systems.. 1679
Subsidiary Apparatus............... 1680
Television and Phototelegraphy....... 1680
Transmission...................... 1681
Tubes and Thermionics............. 1681
Miscellaneous...................... 1682

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

534.1.087:621.395.616 **2275**
Absolute Calibration of a Capacitance-Type Vibration Pickup—(*Tech. News Bull. Natl. Bur. Stand.*, vol. 42, pp. 1–3; January, 1958.) See also 332 of 1958 (Koidan).

534.143:537.528 **2276**
The Electroacoustic Efficiency of a Spark Discharge in Water—N. A. Roĭ and D. P. Frolov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 683–686; February 1, 1958.)

534.232:537.228.1 **2277**
Transients in Piezovibrators—P. V. Ponomarev. (*Akust. Zh.*, vol. 3, pp. 243–253; July, 1957.) An investigation of the operation of a radiating quartz plate excited by pulses of arbitrary shape.

534.232:537.228.1 **2278**
Shift of Resonant Frequencies of a Plane Piezoelectric Radiator with Resistive Load—A. A. Ananeva. (*Akust. Zh.*, vol. 3, pp. 282–285; July, 1957.) Investigation of $BaTiO_3$ ceramics and other piezoelectric materials showed the considerable influence of a resistive load on measurements of resonance frequencies. Results are presented graphically.

534.232-8 **2279**
New Technique for Measuring Transducer Blocked Impedance—G. A. Sabin. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 146–150; February, 1958.) A pulse method for measurements on underwater transducers is described and results for a magnetostrictive transducer resonant at 60 kc are given.

534.232-8:621.318.134 **2280**
Testing Experimental Ferrite Ultrasonic Receivers—I. P. Golyamina, A. D. Sokolov, and V. I. Chulkova. (*Akust. Zh.*, vol. 3, pp. 288–290; July, 1957.) The acoustic properties of some Ni-Zn ferrites used in ultrasonic receivers are reported and the frequency response of Ni ferrite and Ni-Zn ferrites are shown graphically.

The Index to the Abstracts and References published in the PROC. IRE from February, 1957 through January, 1958 is published by the PROC. IRE, May, 1958, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1958 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

534.232-8:621.395.623.52 **2281**
Theory of Ultrasonic Concentrators—L. G. Merkulov. (*Akust. Zh.*, vol. 3, pp. 230–238; July, 1957.) The properties of conical, exponential, and catenary horns are investigated and their characteristics are calculated. Experiments show that the highest magnification is obtained with the catenary type of horn.

534.241 **2282**
Frequency Dependence of Echoes from Bodies of Different Shapes—R. Hickling. (*J. Acoust. Soc., Amer.* vol. 30, pp. 137–139; February, 1958.) It is shown by calculation that the frequency dependence of an echo is different for a prolate spheroid, an infinite cylinder, and a sphere.

534.6:519.272 **2283**
Correlation Method of Measurement of Acoustic Relations—S. G. Gershman and E. F. Orlov. (*Akust. Zh.*, vol. 3, pp. 285–288; July, 1957.) Results of experiments carried out in a building of the Acoustical Institute of the U.S.S.R. are shown graphically and a method for the calculation of transmission losses is described. See also 2501 of 1955 (Goff).

534.76:534.78 **2284**
Stereophonic Listening and Speech Intelligibility against Voice Babble—I. Pollack and J. M. Pickett. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 131–133; February, 1958.) Experiments with earphones confirm that directional information may improve intelligibility.

534.78 **2285**
Masking of Speech by Noise at High Sound Levels—I. Pollack and J. M. Pickett. (*J. Acoust. Soc. Amer.*, vol. 30, pp. 127–130; February, 1958.) Over a wide range of conditions a high level of background noise was found to cause deterioration of speech intelligibility for a constant speech/noise ratio.

534.861 **2286**
Experimental Study of Statistical Properties of Musical and Speech Signals in Broadcasting—B. A. Fersman. (*Akust. Zh.*, vol. 3, pp. 274–281; July, 1957.) An experimental installation for the investigation of the distribution function of instantaneous values of four types of signal is examined. Speech signals have been found to follow a Cauchy type of distribution.

621.395.625.3:621.317.42 **2287**
The Determination of the Magnetization of Magnetic Recording Tape—Schmidbauer. (See 2505.)

ANTENNAS AND TRANSMISSION LINES

621.315.212 **2288**
Attenuation in Continuously Loaded Coaxial Cables—G. Raisbeck. (*Bell Sys. Tech. J.*, vol. 37, pp. 361–374; March, 1958.) A theoretical study of the attenuation in cables loaded with magnetic material is presented. Three parameters are involved, and when the line has optimum dimensions, two parameters determine the attentuation. Graphical and analytical relations are given in forms which can be applied to practical problems.

621.372.2 **2289**
Experimental Check of Formulas for Capacitance of Shielded Balanced-Pair Transmission Line—B. G. King, J. McKenna, and G. Raisbeck. (PROC. IRE, vol. 46, pp. 922–923; May, 1958.) See 1646 of 1957 (Gent).

621.372.43 **2290**
General Synthesis of Quarter-Wave Impedance Transformers—H. J. Riblet. IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 36–43; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.372.8:537.226 **2291**
Losses in Dielectric Image Lines—D. D. King and S. P. Schlesinger. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 31–35; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.372.8:621.372.413 **2292**
Resonance Properties of Ring Circuits—F. J. Tischer. IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 51–56; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.372.821:621.372.832.6 **2293**
Strip-Line Hybrid Junction—H. G. Pascalar. IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 23–30; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.372.825 **2294**
Calculation of Parameters of Ridge Waveguides—Tsung-Shan Chen. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 12–17; January, 1958. Abstract, PROC. IRE, vol. 45, p. 575; April, 1957.

621.372.85+621.315.212]:621.318.134 2295

Ferrite Components in Microwave Systems—B. L. Humphreys. (*Electronic Eng.*, vol. 30, pp. 341–345; May, 1958. A review of circuit techniques.

621.396.67:621.397.62:621.317.3 2296

Measuring TV Aerial Performance—F. R. W. Strafford. (*Wireless World*, vol. 64, pp. 67–69; February, 1958, pp. 120–123; March, 1958, and pp. 294–298; June, 1958.) A minimum height of 25 feet and distance/height ratio of 15 are recommended for the test transmitting and receiving antennas; conditions for accurate measurements and the selection of a suitable test site are discussed. The choice of standard antennas and of radiating and detecting equipment is considered, and methods of presenting gain and directional response characteristics are given. Techniques of antenna impedance measurement and effects of feeder mismatching are discussed.

621.396.67.095 2297

Use of a Fictitious Magnetic Current for the Solution of the Problem of Radiation of an Aerial over a Surface with the Heterogeneous Boundary Conditions of Leontovich—O. N. Tereshin. (*Radiotekhnika*, vol. 12, pp. 24–31; April, 1957.) The conditions are defined in terms of a coefficient α, the ratio of the tangential components of the electric and magnetic fields.

621.396.677.43 2298

The Behaviour of Two Concentric Rhombic Aerials—W. Kronjäger and K. Vogt. (*Nachrtech. Z.*, vol. 10, pp. 494–496; October, 1957.) Measurements of coupling factor, matching, and gain of two rhombics, one of which is placed inside the other, show that the influence of the loaded outer antenna on the inner is negligible. The installation discussed is used for reception in a 4:1 range of frequencies, each antenna covering a range of 2:1.

621.396.677.5 2299

Super Loop Antenna—S. Adachi, J. R. McDougal, and Y. Mushiake. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 9, pp. 1–8; June, 1957.) Measurements of input impedance and directional properties at 120–370 mc are presented for a multi-element antenna consisting of circular loops, positioned concentrically around a supporting pipe of relatively large diameter and connected in parallel at their feed points.

621.396.677.5 2300

Theoretical Formulation for Circular Loop Antennas by Integral Equation Method—S. Adachi and Y. Mushiake. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 9, pp. 9–18; June, 1957.) An integral equation for the current distributions in a loaded circular loop antenna is solved by the successive approximation method, thus leading to expressions for the transmitting and receiving characteristics of a loaded or short-circuited loop antenna at HF.

621.396.677.71 2301

Radiation and Surface Currents from a Slot on an Infinite Conducting Cylinder—F. H. Northover. (*Canad. J. Phys.*, vol. 36, pp. 206–217; February, 1958.) The saddle-point method of calculating the far field, as used by Papas (2715 of 1949) and others, is not valid for points close to the antenna. The basis for a method which overcomes this defect is described. The ranges of validity of this method and of the Papas procedure are discussed.

621.396.677.73 2302

A New Broad-Band Microwave Antenna System—R. W. Friis and A. S. May. (*Commun. and Electronics*, no. 35, pp. 97–100; March, 1958.) The antenna is an electromagnetic horn capped by a sector of a paraboloidal reflector. It is intended for simultaneous operation in the bands 3700–4200 mc, 5925–6425 mc, and 10,700–11,700 mc. Details of gain and directivity are given.

621.396.677.85:629.19 2303

Loaded-Lens Antenna tracks Missiles—L. S. Miller. (*Electronics*, vol. 31. pp. 44–46; March 28, 1958.) An artificial dielectric lens consisting of concentric foam-plastic hemispheres each covered with metal disks is used to provide a circularly polarized feed for a 60-foot paraboloid at 216–245 mc. A waveguide feed allows independent control of E and H-plane patterns, and separate horizontal and vertical polarization outputs provide maximum polarization versatility.

AUTOMATIC COMPUTERS

681.142 2304

Simulation of Nonlinear Field Problems—I. C. Hutcheon. (*Brit. Commun. Electronics*, vol. 5, pp. 96–99; February, 1958.) Some three-dimensional problems can be solved by using a resistance network in conjunction with a single ac amplifier, a function generator, a scanning switch, and a number of simple analog storage units.

681.142:512.831 2305

Matrix Analysis of Logical Networks—E. J. Schubert. (*Commun. and Electronics*, no. 35, pp. 10–13; March, 1958.) "A novel method of matrix algebra is derived for the analysis of networks representing logical systems too complex for conventional approaches using Boolean algebra. It is shown that truth tables of system blocks may be treated as matrices and that logical operations on such matrices can be performed efficiently."

681.142:517.512.2 2306

An Analogue Computer for Fourier Transforms—D. G. Tucker. (*J. Brit. IRE*, vol. 18, pp. 233–235; April, 1958.)

681.142:621.311.25:621.039 2307

Analogue Computers in the Nuclear Power Programme—J. C. Nutter. (*Instrum. Practice*, vol. 12, pp. 46–51; January, 1958.)

681.142:[621.314.63+621.395.1:537.525.92 2308

New Applications of Impedance Networks as Analogue Computers for Electronic Space-Charge and for Semiconductor Diffusion Problems—G. Čremošnik, A. Frei, and M. J. O. Strutt. (Proc. IRE, vol. 46, pp. 868–877; May, 1958.) The general second-order partial differential equation is transformed to the equivalent equation of finite differences and hence relations for analog impedance networks are derived. Resistance chains are applied to the case of one-dimensional high-vacuum diodes yielding results within about 1 per cent of the exact solutions. RC networks are applied to semiconductor diffusion with space and surface recombination, giving some new results for *p–n* diodes. A plane resistance network applied to a triode with space charge gives the anode current/gird voltage curve within a few per cent of the published value. See also 1493 of 1958 (Čremošnik and Strutt) and back references.

681.142:621.314.7 2309

A Basic Transistor Circuit for the Construction of Digital Computing Systems—P. L. Cloot. (*Proc. IEE*, pt. B, vol. 105, pp. 213–220; May, 1958.) A circuit, comprising one transistor, one capacitor, and three resistors, forms the basis of a complete digital computing system for use where high operation speed is not essential. The construction of well-known computer circuits from the basic circuit is described and a complete logical computing system, using 184 circuits, is developed to demonstrate their application.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.75 2310

Printed Wiring—H. Nagatsu and H. Sakai. (*Rep. Elec. Commun. Lab., Japan*, vol. 5, pp. 18–29; December, 1957.) An assessment and detailed description of processes in the production of photo-etched circuits. The properties of the copper foil used are examined and particular attention is paid to the photographic and enamelling techniques and to dip-soldering.

621.314.22 2311

Small Transformers with Low Magnetic Leakage—A. Lang. (*Eletrotech. Z., Ed. A.*, vol. 79, pp. 10–14; January 1, 1958.) The external field characteristics of various types of laminated and C-core transformers are examined to determine the form of construction with lowest leakage.

621.314.22:621.372.512.2 2312

Wide-Band Transformer Characteristics—A. C. Hudson. (*Electronic and Radio Engr.*, vol. 35, pp. 228–234; June, 1958.) "A parameter f_r is defined for wide-band transformers, which represents the series resonance of the leakage inductance and the primary and secondary stray capacitances. It is shown that this parameter may be determined from the low-frequency requirements on the transformer, and then used as a guide to the attainable high-frequency response."

621.318.042.1:538.24 2313

Terminal Properties of Magnetic Cores—T. C. Chen and A. Papoulis. (Proc. IRE, vol. 46, pp. 839–849; May, 1958.) The terminal properties of the cores can be obtained from their dynamic step response; it is shown that for thick (2 mils or more), thin ($\frac{1}{8}$ mil), and intermediate-sized cores there is a unique relation between the flux in the core and the applied coulomb-turns. The analysis is verified by experiment.

621.318.44 2314

New Techniques for Winding Subminiature Coils—W. F. Kallensee. (*Electronic Ind.*, vol. 17, pp. 70–71; January, 1958.) Details of a method for winding self-supporting coils of adhesive-coated wire.

621.318.57:621.314.63 2315

Solid-State Thyratron switches Kilowatts—R. P. Frenzel and F. W. Gutzwiller. (*Electronics*, vol. 31, pp. 52–55; March 28, 1958.) The operation of a controlled silicon rectifier and its application in various switching circuits and converters are described.

621.318.57:621.396.96 2316

Broad-Band Balanced Duplexers—C. W. Jones. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 4–12; January, 1957. Abstract, Proc. IRE, vol. 45, p. 575; April, 1957.)

621.319.4 2317

Research of Condensers and its Results—S. Hayashi, K. Kinugawa, K. Kudo, M. Chiba, and S. Sakurai. (*Rep. Elec. Commun. Lab., Japan*, vol. 5, pp. 30–34; December, 1957.) Voltage, temperature, and frequency characteristics are given for a number of types of capacitor, particularly the $BaTiO_3$ and silvered mica types.

621.319.4.001.4 2318

Accelerated Life Testing of Capacitors—G. J. Levenbach. (IRE Trans. on Reliability and Quality Control, no PGRQC-10, pp.

9–20; June, 1958. Abstract, PROC. IRE, vol. 45, p. 1166; August, 1957.)

621.319.43 2319

Precision Variable Capacitors For High-Grade Electronic Equipment—A. A. Turnbull. (*Brit. Commun. Electronics*, vol. 4, pp. 756–759; December, 1957.) Two types of small variable capacitors are described which were designed to meet stability and accuracy specifications comparable with larger types. One gives a linear frequency variation over 15° of shaft rotation; the other gives a sinusoidal variation of frequency about a mean value as the rotor shaft is turned continuously.

621.372.413 2320

Excitation of Higher-Order Modes in Spherical Cavities—R. N. Ghose. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 18–22; January, 1957. Abstract, PROC. IRE, vol. 45, pp. 575–576; April, 1957.)

621.372.44:621.372.6 2321

Some General Properties of Nonlinear Elements: Part 2—Small-Signal Theory—H. E. Rowe. (PROC. IRE, vol. 46, pp. 850–860; May, 1958.) The analysis of nonlinear capacitor modulators, demodulators, and negative-conductance amplifiers, with only two signal frequencies present, gives results that agree with the general energy relations of Part 1 [2988 of 1956 (Manley and Rowe)]. In addition, the gain, bandwidth, terminal admittances, and sensitivity to changes in terminal admittances or in local-oscillator drive, are given together with their dependence upon the amount of nonlinearity. Generally the bandwidth of these devices approaches zero as the nonlinearity approaches zero.

621.372.44:621.372.632 2322

General Properties of Frequency-Converting Networks—S. Duinker. (*Philips Res. Rep.*, vol. 13, pp. 37–78; February, 1958, and pp. 101–148; April, 1958.) A generalized analysis of frequency-converting systems consisting of networks containing nonlinear inductors, capacitors, and resistors, and including also nonlinear L, C, and R coupling elements. The mesh and nodal equations for a general nonlinear network are given, and it is assumed that a certain high-voltage and current distribution (the so-called fundamental state) results from the presence of (carrier) current and voltage sources. First-order perturbational equations are then derived corresponding to the disturbance of the fundamental state by small (signal) voltage or current sources. Linear differential equations with time-dependent coefficients are obtained, which yield, for a periodic fundamental state, equations in matrix form. Methods of simplifying the matrices are shown, and the method is used to examine stability, conversion gain, and loss. As an example, a polyphase magnetic modulator is analyzed.

621.372.5 2323

Parallel Four-Terminal Networks—F. E. Rogers. (*Electronic and Radio Engr.*, vol. 35, pp. 207–211; June, 1958.) A simple relation exists between the output/input voltage ratio for any number of four-terminal networks in parallel and their parameters of output admittance and short-circuit transfer admittance. The relation enables the voltage ratio to be stated without solving the networks.

621.372.512.3:621.374.4 2324

A Wide-Band Multiplier Unit—G. T. Sassoon. (*R.S.G.B. Bull.*, vol. 33, pp. 360–362; February, 1958.) Capacitive coupling leads to easily adjustable wide-band couplers. A practical design of a wide-band frequency-multiplier unit incorporating these and covering all bands from 3.5 to 28 mc is given.

621.372.54:621.372.412 2325

Ceramic I. F. Filters match Transistors—D. Elders and E. Gikow. (*Electronics*, vol. 31, pp. 59–61; April 25, 1958.) $BaTiO_3$ resonant filters can replace IF transformers with improvement in size, cost, ruggedness, and insertion loss. Their input and output impedances are compatible with those of transistors.

621.372.543 2326

Transient Phenomena in Band Filters—A. Sabbatini. (*Note Recensioni Notiz.*, vol. 6, pp. 625–638; September/October, 1957.) Analysis of a filter consisting of two coupled circuits.

621.373.4 2327

Simultaneous Asynchronous Oscillations in Class-C Oscillators—M. I. Disman and W. A. Edson. (PROC. IRE, vol. 46, pp. 895–903; May, 1958.) It is shown, theoretically and practically, that self-starting asynchronous oscillations are possible in a class-C pentode oscillator. Transient and steady-state solutions are obtained for such an oscillator with one and two degrees of freedom.

621.373.42.029.64:621.3.018.41(083.74) 2328

S.H.F. Frequency Standard uses Double Conversion—Thompson, Vetter, and Waters. (See 2488.)

621.373.421.11 2329

Simultaneous Oscillations at Two Frequencies in a Self-Oscillatory System with Automatic Bias—G. M. Utkin. (*Radiotekhnika, Mosk.*, vol. 12, pp. 64–66; April, 1957.) An investigation of the self-biasing by grid current in an oscillator confirms that oscillations at two different frequencies may occur. See also 1362 of 1958.

621.373.421.14:621.3.018.41(083.74) 2330

An Atomic Reference Oscillator—Capelli. (See 2489.)

621.373.421.14.029.6 2331

Frequency Stabilization of a Microwave Oscillator with an External Cavity—I. Goldstein. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 57–62; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.373.431.1.018.756 2332

Multivibrator Circuit for Millimicrosecond Pulses—W. Gruhle. (*Elektronik*, vol. 6, pp. 261–263; September, 1957) Pulse rise times of about 20 mμsec and a repetition frequency of several mc can be achieved with the tube circuit described. Pulse width can be adjusted continuously without affecting the rise time.

621.373.44 2333

Precision Pulse Generator—H. L. Miller. (IRE TRANS. ON NUCLEAR SCIENCE, vol. NS-3, pp. 18–21; June, 1956. Abstract, PROC. IRE, vol. 44, p. 1084; August, 1956.)

621.374.32:621.314.7 2334

Dekatrons and Electromechanical Registers Operated by Transistors—G. B. B. Chaplin and R. Williamson. (*Proc. IEE*, pt B, vol. 105, pp. 231–236; May, 1958. Discussion, pp. 266–272.) Transistor circuits are described for driving cold-cathode decade tubes and electromechanical counters. In both cases the transistor circuit combines the waveform-shaping properties of the thermionic valve with the economy of power achieved with the cold-cathode valve. High reliability of performance is also attained.

621.374.4:621.318.4:621.397.6 2335

Magnetic-Core Dividers for ITV Sync Generators—A. Rose. (*Electronics*, vol. 31, pp. 76–77; April 11, 1958.) An accurate and stable digital divider can be made with a pair of magnetic cores having rectangular hysteresis loops. Division by factors up to 17 has been obtained in a single stage in the frequency range 10–50 kc.

621.375.1 2336

On the Problem of Synthesis of Amplifier Circuits—S. V. Samsonenko. (*Radiotekhnika, Mosk.*, vol. 12, pp. 45–57; April, 1957.) A new mathematical method is described for the analysis of transients in amplifiers and a means of synthesis is suggested for multistage systems considering different types of distortion.

621.375.13+621–52 2337

Design of Conditionally Stable Feedback Systems—J. Ôizumi and M. Kimura. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 9, pp. 19–38; June, 1957.) Conditionally stable systems are shown to have a greater feedback than that obtainable from unconditionally stable feedback circuits. The design of such systems is analyzed mathematically and a practical method for automatically preventing oscillation occurring in them is suggested. Experimental results obtained with a suitable circuit are presented.

621.375.3 2338

Some Aspects of Half-Wave Magnetic Amplifiers—G. M. Ettinger. (*Proc. IEE*, pt B, vol. 105, pp. 237–248; May, 1958. Discussion, pp. 266–272.) The performance of half-wave magnetic amplifiers is analyzed and a theory presented which allows for a finite control-circuit resistance, or rectifier reverse conductance, and imperfect core properties. Experimental results obtained with amplifiers using different cores show good agreement with theory. Various methods of bias are reviewed and a conductance-controlled amplifier is described.

621.375.3 2339

A Fast-Response Full-Wave Magnetic Amplifier—G. E. Lynn. (*Commun. and Electronics*, no. 35, pp. 37–41; March, 1958.)

621.375.3 2340

The Effective Feedback Factor of Self-Balancing Magnetic Amplifiers—W. A. Geyger. (*Commun. and Electronics*, no. 35, pp. 66–69; March, 1958.)

621.375.4.011.21 2341

Three Output Immittance Theorems—H. Stockman. (*Electronic Ind.*, vol. 17, pp. 61–63, 156; January, 1958.) A discussion of various theorems having practical application in the analysis of transistor circuits.

621.375.4.018.783 2342

Nonlinear Distortion in Transistor Amplifiers—G. Meyer-Brötz and K. Felle. (*Elektron Rundschau*, vol. 11, pp. 297–301; October, 1957.) Following an analysis of the causes of distortion in common-emitter circuits, the distortion factor is derived from the static characteristics. The dependence of distortion on temperature, collector bias, input signal level, and load resistance is determined, and calculated values are compared with results of measurements.

621.375.4.024 2343

Some Transistor Input Stages for High-Gain D.C. Amplifiers—G. B. B. Chaplin and A. R. Owens. (*Proc. IEE*, pt B, vol. 105, pp. 249–257; May, 1958. Discussion, pp. 266–272.) Several types of input stage are investigated and methods of reducing drift are suggested. It is shown that drift of operating point in transistor dc amplifiers depends on the type of

circuit; the lowest drift being obtained using the transistor as a chopper.

621.375.4.024 2344

A Transistor High-Gain Chopper-Type D.C. Amplifier—G. B. B. Chaplin and A. R. Owens. (*Proc. IEE*, pt B, vol. 105, pp. 258–266; May, 1958. Discussion, pp. 266–272.) A modulated system is employed consisting of a transistor input chopper; a high-gain transistor ac amplifier and an output chopper. The system has an open loop gain of 500 v/μa with a band extending from direct current to 25 cps. Peak output is ±10 volts and current drift referred to input is 4×10^{-9}a in the range 20°C–50°C. The voltage drift at the input is less than 100μa.

621.375.4.029.3 2345

Designing Transistor A.F. Power Amplifiers—M. B. Herscher. (*Electronics*, vol. 31, pp. 96–99; April 11, 1958.) The amplifier described delivers 45 w to a 4-Ω load. It contains a driver stage, a phase splitter using a transistor pair, and a push-pull output-stage.

621.375.9:538.569.4.029.6 2346

Operation of a Solid-State Quantum-Mechanical Amplifier—M. W. P. Strandberg, C. F. Davis, B. W. Faughnan, R. L. Kyhl, and G. J. Wolga. (*Phys. Rev.*, vol. 109, pp. 1988–1989; March 15, 1958.) "The operation of an S-band solid state quantum-mechanical amplifier operated at 4.2°K with a computed noise temperature of less than 4.5°K is compared with similar devices and is used as proof of the condition of discrete phonon saturation which has been previously postulated." See also 1691 of 1958 (McWhorter and Meyer).

621.375.9:538.569.4.029.6 2347

The Solid-State Maser—a Supercooled Amplifier—J. W. Meyer. (*Electronics*, vol. 31, pp. 66–71; April 25, 1958.) A review of maser techniques with descriptions of two-level molecular-beam and three-level solid-state devices. Amplifier and oscillator characteristics, noise measurements, and future developments are discussed.

621.375.9:538.569.4.029.6 2348

A U.H.F. Solid-State Maser—R. H. Kingston. (PROC. IRE, vol. 46, p. 916; May, 1958.) Maser action at a frequency of 300 mc has been obtained by using a cavity mode at the pumping frequency and a lumped resonant circuit at the amplifying frequency.

621.375.9:538.569.4.029.6 2349

Design Considerations for Circulator Maser Systems—F. R. Arams and G. Krayer. (PROC. IRE, vol. 46, pp. 912–913; May, 1958.) A general expression for effective maser system noise temperature is calculated and a working approximation is derived. The noise and stability requirements for a low-noise circulator maser system are given in terms of maser gain and of dissipative losses and SWR in various parts of the system.

621.375.9:538.569.4.029.6:621.396.822 2350

System-Noise Measurement of a Solid-State Maser—A. L. McWhorter and F. R. Arams. (PROC. IRE, vol. 46, pp. 913–914; May, 1958.) A complete amplifier system with an effective input noise temperature of 20±5°K is described. The sources of noise are analyzed and it is shown that the noise temperature of the maser proper is close to the theoretical value.

621.375.9:538.569.4.029.64 2351

Electron Spin and Phonon Equilibrium in Masers—Bloembergen. (See 2385.)

621.375.9:621.372.2 2352

A Travelling-Wave Parametric Amplifier—A. L. Cullen. (*Nature, London*, vol. 181, p. 332; February 1, 1958.) A lossless transmission line with periodically varying distributed inductance and a constant distributed capacitance will support a growing current wave. For maximum amplification the oscillator used for providing the periodic variation of inductance must be synchronized with the incoming signal. The noise figure of such an amplifier should be very favorable. An experimental investigation is in progress, and related schemes are being studied in which precise frequency and phase relations are not demanded.

621.375.9.029.6:537.311.33 2353

Proposed Negative-Mass Microwave Amplifier—H. Krömer. (*Phys. Rev.*, vol. 109, p. 1856; March 1, 1958.) It is pointed out that negative masses occur in semiconductors at energies close to the band edge if the energy contours are re-entrant there. It is suggested that such a semiconductor might be used as the active element in a microwave amplifier, although preliminary experiments with germanium did not show the effect. See also 2901 of 1954 (Shockley and Mason).

GENERAL PHYSICS

533.6.011 2354

On Chandrasekhar's Theory of Turbulence—P. C. Jain. (*Proc. Nat. Inst. Sci. India.*, pt A, vol. 23, pp. 504–513; November 26, 1957.) The theory (*Proc. Roy. Soc. A*, vol. 229, pp. 1–19; April 5, 1955.) has been generalized to the case of axisymmetric turbulence, and eight differential equations in eight defining scalars of double and triple correlation tensors deduced. Two of these equations replace that of de Kármán and Howarth (*Proc. Roy. Soc. A*, vol. 164, pp. 192–215; January 21, 1938) in the theory of isotropic turbulence.

533.6.011 2355

On Decay of Energy Spectrum of Isotropic Turbulence—N. R. Sen. (*Proc. Nat. Inst. Sci. India*, pt A, vol. 23, pp. 530–533; November 26, 1957.)

535.215:537.224 2356

Electric Field Distribution in Polarized Photoconductors—H. Kallmann and J. R. Freeman. (*Phys. Rev.*, vol. 109, pp. 1506–1508; March 1, 1958.) The distribution is determined from changes which occur in the persistent polarization [see 2633 of 1955 (Kallmann and Rosenberg)] under various polarizing conditions.

537.12:537.311.1 2357

The Fundamental State of an Electron Gas—H. Koppe. (*Z. Physik*, vol. 148, pp. 135–155; April 3, 1957.) Detailed discussion with reference to Mayer's treatment of electron correlation energy (*Phys. Rev.*, vol. 100, pp. 1579–1586; December 15, 1955).

537.226 2358

Force Densities in Dielectrics—É. Durand. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1003–1006; September 16, 1957.)

537.311.1 2359

A New Approach to the Theory of Electrical Conductivity of Solids—B. Meltzer. (*Physica*, vol. 23, pp. 118–124; February, 1957.) Since the electrical conductance of a body is a measure of the fluctuations of charge in a state of thermodynamic equilibrium an analysis of these fluctuations gives the value of the conductivity. The value derived agrees with that of Drude but is found to be half that for the Lorentz-Sommerfeld model.

537.311.1 2360

The Boltzmann Equation in the Theory of Electrical Conduction in Metals—D. A. Greenwood. (*Proc. Phys. Soc. London*, vol. 71, pp. 585–596; April 1, 1958.) The Boltzmann equation for electrical conduction in metals is derived assuming $\hbar/\tau \ll kT$, where τ is the collision time. An expression independent of this assumption is considered but not evaluated.

537.311.1 2361

Theory of Electrical Conductivity of Anisotropic Inhomogeneous Media—A. Nedoluha. (*Z. Physik*, vol. 148, pp. 248–252; April 13, 1957.)

537.311.31:538.63 2362

Quantum Theory of the Electrical Conductivity of Metals in a Magnetic Field—I. M. Lifshits. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1509–1518; June, 1957.) The kinetic equation for the density matrix is derived and the asymptotic values of the kinetic coefficients in a strong magnetic field are analyzed.

537.56 2363

On the Theory of Spectral-Line Broadening in Plasma—V. I. Kogan. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 907–910; February 11, 1958.)

537.56 2364

Structure of Shock Waves in a Plasma—V. D. Shafranov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1453–1459; June, 1957.) Investigation of a shock wave in a plasma taking account of the difference in electron and ion temperatures. Three cases are examined: a) nonstationary shock wave, b) stationary shock wave, and c) stationary shock-wave in a strong magnetic field.

537.56 2365

Electrodynamical Acceleration of Plasma Bunches—L. A. Artsimovich, S. Yu. Luk'ianov, I. M. Podgornyĭ, and S. A. Chuvatin. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 3–8; July, 1957.) A method is described of generating a gas-discharge plasma by the electric explosion of a 0.02 mm-diameter copper wire in a discharge chamber evacuated to $1-2\times10^{-6}$ mm Hg. A 75-μf capacitor is used with initial voltage 30 kv.

537.56 2366

Quantum Kinetic Equation for Plasma taking Account of Correlation—Yu L. Klimontovich and S. V. Temko. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 132–134; July, 1957.) A quantum kinetic equation for a system of particles with coulomb interaction is derived taking into account the correlation of the mutual position of the charged particles.

537.56 2367

On the Effective Field in a Plasma—B. B. Kadomtsev. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 151–157; July, 1957.) Equations for the partial distribution functions are used to compute the effective field acting on charged particles in a plasma. The effective field differs from the mean field by a small quantity of the order of $1/N$ where N is the number of particles within a sphere of radius equal to the Debye radius.

537.56:538.56 2368

The Dispersion Equation for Plasma Waves—N. G. Van Kampen. (*Physica*, vol. 23, pp. 641–650; July, 1957.) The validity of different formulas is discussed. When collisions are infrequent no dispersion equation exists except in special cases. See also 2029 of 1956.

537.56:538.569 2369

On the Dynamics of a Bounded Plasma in an External Field—L. M. Kovrizhnykh. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 72–76; July, 1957.) An investigation of the dynamics of a quasi-neutral plasma formation located in the field of a plane electromagnetic wave. The method of successive approximations is used. Within the limits of the assumptions of the analysis a plasma bunch tends to spread out.

537.56:538.6:52 2370

An Energy Principle for Hydromagnetic Stability Problems—I. B. Bernstein, E. A. Frieman, M. D. Kruskal, and R. M. Kulsrud. (*Proc. Roy. Soc. A*, vol. 244, pp. 17–40; February 25, 1958.) The problem of the stability of static, highly conducting, fully ionized plasmas is investigated by means of an energy principle developed from one introduced by Lundquist (122 of 1952). The method is applied to the general axisymmetric system and to plasmas which are completely separated from the magnetic field by an interface.

537.56:538.63:538.56 2371

Radiation of Plasma in a Magnetic Field—B. A. Trubnikov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 913–916; February 11, 1958.) Mathematical analysis of electromagnetic radiation in plasma taking account of electron spin in a uniform magnetic field.

537.56:538.63:538.566 2372

Coherent Scattering and Radiation of Electromagnetic Waves by Plasma in an Inhomogeneous Magnetic Field—G. A. Askar'yan. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1576–1577; June, 1957.) The propagation of quasi-plane waves in a waveguide filled with plasma in a longitudinal magnetic field and the radiation in an electron plasma of a bunch which travels through a spatially periodic axially symmetric magnetic field are discussed. The plasma tends to focus the bunches and a longitudinal focusing effect results from the attraction between the induced currents flowing in the same direction.

538.114 2373

Models Demonstrating the Phenomena of Ferromagnetic Hysteresis—H. Wilde. (*Nachrtech. Z.*, vol. 10, pp. 497–502; October, 1957.) Extension and refinement of the Preisach model. See also 842 of 1957 (Feldtkeller and Wilde).

538.222:539.2 2374

Contribution to the Phenomenological Theory of Paramagnetic Relaxation in Parallel Fields—N. K. Belousova and I. G. Shaposhnikov. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 238–242; July, 1957.) The role of spin-lattice interaction is examined and the applicability of the results of this analysis to paramagnetic absorption at high frequencies and temperatures of the order of 20°K is considered.

538.3 2375

The Classical Electromagnetic Equations expressed as Complex Four-Dimensional Quantities—E. F. Bolinder. (*J. Franklin Inst.*, vol. 263, pp. 213–223; March, 1957.) It is possible to compress the classical electromagnetic equations into three complex four-dimensional quantities representing, respectively, electromagnetic fields, currents and charges, and vector and scalar potentials. This notation is useful in problems relating to waveguides, cavities, and antennas for microwaves.

538.3:52 2376

Theory of Magnetohydrodynamic Waves using the Energy Pulse Tensor of Abraham—E. Richter. (*Z. Physik*, vol. 148, pp. 253–261; April 3, 1957.) See also 2423 of 1957.

538.3:52 2377

Dynamo Effect in Magnetohydrodynamic Theory—S. Colombo. (*Rev. gén. Élect.*, vol. 66, pp. 325–332; June, 1957.)

538.52:538.566 2378

Surface Currents Induced by Short-Wavelength Radiation—J. A. Cullen. (*Phys. Rev.*, vol. 109, pp. 1863–1867; March 15, 1958.) "The integral equation given by Fock [1412 of 1947] for the surface currents induced in a perfectly conducting convex object by short-wavelength plane electromagnetic waves is solved directly by the method of Fourier transforms. The result agrees with Fock's indirect approach. Some general properties of the equation are also discussed."

538.561:537.56:53.087:621.383.27 2379

The Cherenkov Effect Produced by Single Particles in Gases—A. Ascoli-Balzanelli and R. Ascoli. (*Nuovo Cim.*, vol. 6, pp. 1392–1408; December 1, 1957.) (In English.) The application of photomultipliers for detecting Cherenkov radiation is discussed and successful experimental work is reported.

538.566:535.42 2380

A New Formulation of Scalar Diffraction Theory for Restricted Aperture—J. M. Cowley and A. F. Moodie. (*Proc. Phys. Soc. London*, vol. 71, pp. 533–545; April 1, 1958.)

538.566:537.53 2381

Radiation of Charged Particles in Flight Past Ideally Conducting Bodies—Yu. N. Dnestrovskiĭ and D. P. Kostomarov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 116, pp. 377–380; September 21, 1957.) The problem is discussed in the nonrelativistic approximation and the induced charge and currents are calculated initially without considering retardation. The radiation due to the current system determined is then estimated. The dipole approximation is used to derive expressions for the rate at which energy is radiated. The radiation resistance for a waveguide system is calculated and its dependence on the particle velocity and on the radius/wavelength ratio is shown graphically.

538.566.029.65:537.228.5 2382

Stark Effect at 2.0 and 1.2 Millimetres Wavelength: Nitric Oxide—C. A. Burrus and J. D. Graybeal. (*Phys. Rev.*, vol. 109, pp. 1553–1556; March 1, 1958.) "Stark-effect measurements have been made for the first time in the 1–2-mm wave region. Results of Stark-effect measurements on the $J=\frac{1}{2}\rightarrow 3/2$ and $J\rightarrow 3/2\rightarrow 5/2$ transitions of the ${}^2\Pi_{1/2}$ ground state of $N^{14}O^{16}$, falling at 2.0 and 1.2 mm, respectively, are reported, and are shown to fit closely existing theory; the electric dipole moment of NO in the ground state is found to be 0.158 ± 0.006 Debye unit."

538.569.4.029.6 2383

Electric Susceptibility of Ethyl Chloride in the Centimetre Region—G. P. Srivastava. (*Z. Physik*, vol. 148, pp. 242–247; April 3, 1957.) (In English.) Results of measurements at 8780 mc over a pressure range 10–75 cm Hg and a temperature range 263°–353° K are discussed. See also 3841 of 1957 (Krishnaji and Srivastava).

538.569.4.029.64:621.375.9 2384

Electron Spin and Phonon Equilibrium in Masers—N. Bleembergen. (*Phys. Rev.*, vol. 109, pp. 2209–2210; March 15, 1958.) It is pointed out that the successful operation of $KCo(Cr)(CN)_6$ in three-level steady-state masers is incompatible, regardless of the operating frequencies of the maser, with the assumption that the relaxation rates are determined by the interaction between the lattice vibrations and the helium bath [see *ibid.*, vol. 109, pp. 302–311; January 15, 1958.) (Giordmaine *et al.*)].

539.1.01:538.569.4 2385

Identity of Spin Temperature and Thermodynamic Temperature—A. Abragam and W. Proctor. (*C.R. Acad. Sci., Paris*, vol. 245, pp. 1048–1050; September 23, 1957.)

539.2:537.311.1 2386

Generalized Mobility Theory—M. Lax. (*Phys. Rev.*, vol. 109, pp. 1921–1926; March 15, 1958.) A formal theory of mobility is presented that does not depend on the existence of a transport equation. In particular the Hamiltonian describing the electron plus the scattering system is not decomposed into an unperturbed part plus a perturbation. Only the applied field is treated as small. The result is shown to reduce to the usual transport result when the scattering perturbation is weak, without assuming the existence of a relaxation time. The relation between a many-electron treatment and the one-electron treatment is demonstrated for the case of Fermi as well as Boltzmann statistics.

539.2:537.311.31:061.3 2387

The Band Theory of Metals—(*Nature, London*, vol. 181, pp. 525–527; February 22, 1958.) Brief report of a conference held by the Physical Society at Imperial College, London, December 20–21, 1957. Some 20 papers are noted.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164:523.35 2388

A "Lunar" Radio Interferometer—G. A. Gurzadyan. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 1094–1097; February 21, 1958.) In a two-antenna interferometer used in radio astronomy one of the antennas can be replaced by the surface of the sea. In the instrument described the ionosphere of the moon is used in place of the second antenna. With meter wavelengths the minimum angle of refraction of the lunar ionosphere is found to be of the order of 0.1′–0.2′.

523.164.31:523.35 2389

Radio Interference Phenomena due to the Ionosphere of the Moon—G. A. Gurzadyan. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 884–887; February 11, 1958.) An attempt to explain the increase of solar radio emission observed before and after a solar eclipse, by interference effects due to refraction of radio waves in the lunar ionosphere.

523.164.32 2390

A Remarkable Solar Radio Event—(*Nature, London*, vol. 181, pp. 542–543; February 22, 1958.) Increased solar radio noise at a frequency of 200 mc was recorded at Nera Observatory, Netherlands, from 0848 V.T. on November 4, 1957. The maximum value was approximately 900 times the noise level of the quiet sun. Fluctuations with a period of 0.2–0.3 second occurred and are attributed to solar phenomena.

523.164.32:621.396.677.833 2391

A Radio Image of the Sun on 3.2-cm Wavelength—V. V. Vitkevich, A. D. Kuz'min, A. E. Salomonovich, and V. A. Udal'tsov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 1091–1093; February 21, 1958.) In June, 1957 at a station of the Physical Institute in the Crimea a new stationary radio telescope with a parabolic reflector of 31 inches diameter, was put into commission. Isophotes of the sun obtained at 3.2 and 10.0 cmλ are shown.

523.165 2392

Energy Spectrum of Cosmic Radiation—H. Alfvén and E. Åström. (*Nature, London*, vol. 181, pp. 330–331; February 1, 1958.) A theory is given for the observed spectrum $f=\text{const.}\ p^{-n}$ where $n=2.5$ for a wide range of values of momentum p.

23.5:621.396.11 2393

Diurnal Variation in the Number of Shower Ieteors Detected by the Forward Scattering f Radio Waves: Part 3—Ellipsoidal Theory— . O. Hines. (*Canad. J. Phys.*, vol. 36, pp. 117–26; January, 1958.) The ellipsoidal geometry herent in the forward-scatter process is deeloped fully. The more rigorous results obined are compared at various stages in the nalysis with those given by the simplifying cylindrical approximation" developed in Part (738 of 1956). The "potentially observable" ails are first located and their distribution dermined. The fraction of these providing a gnal exceeding some given level is found and e total number of these observable trails as function of trail orientation is determined by tegrating over the spatial distribution. Part : 1046 of 1956 (Forsyth *et al.*).

23.5:621.396.11 2394

Resonance Effects in the Theory of Meteor bservability—D. R. Moorcroft and C. O. lines. (*Canad. J. Phys.*, vol. 36, pp. 134–136; anuary, 1958.) The observability theory for rward scattering is revised to cover the resoance that occurs when there is a component f the incident electric vector transverse to the xis of the meteor trail. Normalized contours re given.

23.75:523.165 2395

Solar Activity and Cosmic Radiation—R. R. rown. (*J. Geomag. Geoelect.*, vol. 9, no. 2, pp. 9–85; 1957.) Experimental observations of osmic radiation during intense solar activity re presented and examined with particular ttention to the period around the solar flare of ebruary 23, 1956. The results obtained are disussed in relation to models of solar activity volving corpuscular streams.

23.75:550.385.4 2396

On the Asymmetry of the Heliographic Disibution of the Storm-Producing Probability f Flares—Y. Hakura. (*J. Radio Res. Labs. apan*, vol. 5, pp. 57–64; January, 1958.) The robability is greatest for flares near the center f the disk and for those in the NE and SW uadrants. The greater probability for flares in e western hemisphere is not statistically sigificant.

23.755:523.72 2397

The Distribution over the Emitting Area of Radiation from the Solar Corona and the esidual Intensity during Total Solar Eclipses -G. Elwert. (*J. Atmos. Terr. Phys.*, vol. 12, s. 2/3, pp. 187–199; 1958.) (In German.) The layer is assumed to be ionized by X rays of proximate wavelength 50–100 Å. The intenty of coronal radiation in this waveband is lculated and the results lead to a considerle degree of limb-brightening and to emission radiation at radii greater than that of the sible disk. The intensity of the residual radian during total eclipses can be calculated and estimated to have been about 20 per cent in 52 and 1954, and about 10 per cent in 1955.

0. 385:523.75 2398

Magnetic Activity following a Solar Flare— . A. Ellison. (*J. Atmos. Terr. Phys.*, vol. 12, s. 2/3, pp. 214–215; 1958.) The conclusions ached by Watson (3853 of 1957) that solar res and increases of magnetic activity are not rrelated is not correct. When the magnitude the flare and its position on the disk are ken into account, there is a positive correlan as was shown by Newton (see, *e.g.*, 3398 1944).

0.389.2 2399

International Geophysical Year—H. Odiaw. (*Science*, vol. 127, pp. 115–128; January 1958.) A report on the U. S. program with a brief account of some of the activities during the first five months.

550.389.2:629.19 2400

Estimating the Life of a Satellite—J. M. C. Scott. (*Nature, London*, vol. 180, pp. 1467–1468; December 28, 1957.)

550.389.2:629.19 2401

Lifetime of an Artificial Earth Satellite— D. C. M. Leslie. (*Nature, London*, vol. 180, pp. 403–404; February 8, 1958.) The approximate formulas given by Fejer (2087 of 1958) and Scott (2400 above) are compared with those given by a more exact method and found to be accurate provided the eccentricity is not large.

550.389.2:629.19 2402

British Radio Observation of the Satellite— (*Brit. Commun. Electronics*, vol. 4, pp. 770–772; December, 1957.) Brief reports of the observations made on the first Russian satellite at the B.B.C. Station, Tatsfield, the Radio Research Station, Slough, and Ministry of Supply establishments are given. These include measurements of the signal characteristics, field strength, Doppler frequency shift, and bearing and elevation of the satellite.

551.510.535 2403

The Effect of Diffusion on the Vertical Distribution of Ionization in a Quiet F Region— V. C. A. Ferraro and I. Özdoğan. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 140–149; 1958.) Electrons are assumed to disappear by attachment to neutral molecules and by diffusion. The coefficient of attachment is assumed to be constant while the diffusion constant is calculated according to classical theory. Using rocket measurements of air density and temperature, the vertical distribution of electrons can be calculated. The results are at variance with those actually observed, possibly because the diffusion constant is much less than that assumed.

551.510.535 2404

Ambipolar Diffusion in the F_2 Layer— A. Dalgarno. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 219–220; 1958.) Diffusion in the F_2 layer probably depends on the diffusion of O^+ in O; the coefficient is estimated to be about one quarter of the value normally assumed to be applicable in the F_2 layer.

551.510.535 2405

Horizontal Wind Systems in the Ionospheric E Region Deduced from the Dynamo Theory of the Geomagnetic *Sq* Variation— (*J. Geomag. Geoelect.*, vol. 9, no. 2; 1957.)

Part 3—H. Maeda. (pp. 86–93.) Wind systems are deduced from *Sq* data for the solstice seasons in both northern and southern hemispheres and the diurnal and semi-diurnal components are examined. A comparison of the theoretical system with observed winds is made.

Part 4—S. Kato. (pp. 107–115.) Wind velocities are calculated taking account of Coriolis forces and assuming the electron density at night to be 1/12th that at noon.

Parts 1 and 2: 1080 of 1957.

551.510.535 2406

Non-Chapmanlike Variations in the Ionospheric E and F_1 Layers. Effect of the *Sq* Current System: Part 2—T. Shimazaki. (*J. Radio Res. Labs, Japan*, vol. 5, pp. 35–56; January, 1958.) Variations in f_0E and f_0F_1 are examined in various months in addition to those of March which have already been discussed (see 3472 of 1957). It is shown that, in non-equinoctial months, f_0E is larger in the winter hemisphere than in the summer hemisphere for the same solar zenith distance. This unsymmetrical distribution is interpreted as being due to the *Sq* current system effect in the E layer, the *Sq* current system developing more strongly in summer than in winter. Somewhat similar results are observed for the F_1 layer but detailed examination shows that they can be explained by the temperature difference between the summer and winter hemispheres.

551.510.535:523.164 2407

Radio-Star Scintillations at an Equatorial Station—J. R. Koster. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 100–109; 1958.) Scintillation of radio stars has been measured at 45 mc in Ghana for four years. It is unusually intense, occurs only at night, and is correlated with spread echoes from the F layer and with equatorial scatter of radio signals near sunspot maximum.

551.510.535:523.164 2408

The Diurnal and Seasonal Variations of Spread-F Ionospheric Echoes and the Scintillations of a Radio Star—B. H. Briggs. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 89–99; 1958.) The degree of spreading is greater at Inverness (57°N) than at Slough (52°N) but the diurnal and seasonal variations are similar and can be correlated with the scintillations of the radio star in Cassiopeia provided an allowance is made for the zenith angle of the star. See also 1737 of 1958.

551.510.535:523.746 2409

A Method of Determining the Correlation between f_0F_2 and Sunspot Number—H. Shibata. (*J. Radio Res. Labs. Japan*, vol. 5, pp. 65–73; January, 1958.) The monthly median critical frequency f and the smoothed sunspot number R can be represented for a month m and time of day t by $f(m, t) = a(m, t)R + b(m, t)$. The continuous periodic functions a and b are examined using data obtained at six places in Japan.

551.510.535:523.75:621.396.11 2410

Solar Activity and the Ionosphere—C. M. Minnis. (*Nature, London*, vol. 181, pp. 543–544; February 22, 1958.) Observations at Slough showed that the intensity of the ultraviolet and X radiation responsible for the existence of the E layer of the ionosphere, was higher in September, October, and November, 1957 than ever before recorded, and that on individual days in November the critical frequency of the F_2 layer at noon was above 16 mc. See also 1153 of 1958 (Bennington).

551.510.535:550.385 2411

Disturbances in the Ionospheric F_2 Region associated with Geomagnetic Storms: Part 3—Auroral Latitudes—T. Sato. (*J. Geomag. Geoelect.*, vol. 9, no. 2, pp. 94–106; 1957.) Results of a statistical treatment show that the deviation of f_0F_2 on a disturbed day is similar to the negative disturbance in middle latitudes (see Part 2: 127 of 1958); the deviation of h_pF_2 is different. Main features of the F_2 disturbances can be accounted for by vertical electron drift.

551.510.535:621.396.11 2412

Electron Density Fluctuations and Scattering of Radio Waves in the Ionosphere—Ya. L. Al'pert. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 213–225; July, 1957.) Discussion of theoretical and experimental determinations of electron density fluctuations and of energy scattered at VHF indicates that in vertical-incidence soundings at frequencies below the critical frequency the scattered field is chiefly due to waves first scattered in the forward direction and then reflected from higher levels in the ionosphere.

551.510.535:621.396.11 2413

Control of the Ionosphere by Means of Radio Waves—V. A. Bailey. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 216–217; 1958.) A note on the possibility of using radio waves near the gyrofrequency of electrons in the ionosphere to control the electron temperature and hence the rates of diffusion, attachment, and recombination.

551.510.535:621.296.11.029.62:629.136.3 2414

An Artificial Ionosphere—(*Brit. Commun. Electronics*, vol. 5, p. 117; February, 1958.) The release from rockets of potassium into the high atmosphere produces an ionized cloud, lasting for about an hour, suitable for returning microwave signals.

551.594.2 2415

Waveform Studies of Electric Field Changes during Cloud-to-Cloud Lightning Discharges—B. A. P. Tantry, R. S. Srivastava, and S. R. Khastgir. (*Proc. Natl. Inst. Sci. India*, pt. A, vol. 23, pp. 499–503; November 26, 1957.) Assuming that cloud-to-cloud discharges may be identified from the sign of the field change and the time separation of the individual strokes, such discharges exhibit all the features known to be associated with ground discharges. They include: a) precursors, b) multiple strokes, c) return strokes, d) slow field changes and "hook" components, and e) junction field changes between strokes.

551.594.5 2416

Auroral Display Observed from Unusually Low Geomagnetic Latitudes—B. McInnes. (*Met. Mag. London*, vol. 86, pp. 114–117; April, 1957.) Observations of the aurora display of September 8, 1956 are reported with brief details of some related effects.

551.594.5 2417

Horizontal Movements of Aurora—J. S. Kim and B. W. Currie. (*Canad. J. Phys.*, vol. 36, pp. 160–170; February, 1958.) The drift of auroral forms has been measured at three stations in Canada south of the auroral zone. No evidence is found of a motion due to the earth's rotation relative to a fixed point in space. The distribution and magnitude of the drift speeds parallel and normal to the geomagnetic meridians are similar to those found for ionospheric drifts. The drift speeds increase with geomagnetic activity particularly in an E-W direction.

551.594.5:621.396.96 2418

A Continuously Recording Automatic Auroral Radar—A. G. McNamara. (*Canad. J. Phys.*, vol. 36, pp. 1–8; January, 1958.) A low-power 50-mc system with fixed antennas is used to give a continuous photographic record. The echo intensity is also integrated electronically to give a chart record which is immediately available.

551.594.6 2419

Abnormal Polarization of the Atmospheric Pulses Reflected Successively from the Ionosphere—S. R. Khastgir. (*Nature, London*, vol. 181, pp. 404–405; February 8, 1958.) Elliptic patterns of gradually decreasing eccentricity and tilt angle have been observed in cathode-ray direction finders used to record atmospherics due to lightning discharges at a distance of about 500 km.

551.594.6:621.396.11.029.45 2420

Electromagnetic Radiation from Lightning Strokes—E. L. Hill. (*J. Franklin Inst.*, vol. 263, pp. 107–119; February, 1957.) A theory is given of the spectral distribution and the amount of VLF radiation emitted from a vertical lightning stroke from cloud to ground. The radiated energy has a maximum intensity at about 11 kc and a total width at half-maximum of 12 kc. The total energy radiated in one leader and return stroke is estimated to be about 220,000 joules.

551.594.6:621.396.822 2421

Atmospheric Radio Noise at Frequencies between 10 kc/s and 30 kc/s—J. Harwood. (*Proc. IEE*, pt. B, vol. 105, pp. 293–300; May, 1958.) The results are described in terms of a voltage envelope at the output of a narrow-band receiver (300 cps between 3 db points). The rms voltage deduced by integrating the measured amplitude distributions varies between four and eight times the average voltage. The noise is always much more impulsive than fluctuation noise. The structure of the voltage envelope is considered in two ways: a) the amplitude distribution of pulse peaks and b) the amplitude distribution of voltage. See also 445 of 1957 (Horner and Harwood).

LOCATION AND AIDS TO NAVIGATION

621.396.933.1 2422

Marconi Doppler Navigator—*Wireless World*, vol. 64, pp. 260–261; June, 1958.) Further technical details are given and performance during a demonstration flight is described. See also 3146 of 1957.

621.396.96:551.594.5 2423

A Continuously Recording Automatic Auroral Radar—McNamara. (See 2418.)

621.396.969.33 2424

A Doppler Collision Course Indicator for Use at Sea—H. R. Whitfield and C. M. Cade. (*J. Inst. Nav.*, vol. 11, pp. 81–87; January, 1958.) A system is proposed for the instantaneous measurement of the radial component of relative velocity. This, together with the range and bearing data from a PPI, gives the aspect of the target. Possible errors in deducing true aspect and speed are discussed and the mode of operation and principal design parameters of a suitable Doppler radar are given.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215:537.311.33 2425

Temperature Dependence of Photoelectromotive Force—F. F. Kodzhespirov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1593–1594; June, 1957.) The difficulties of reconciling experimental results with theories concerning photoelectric effects are considered. The temperature dependence of the EMF is discussed with reference to amorphous Se exposed to X rays of different intensity.

535.215:546.472.21 2426

Photovoltages Larger than the Band Gap in Zinc Sulphide Crystals—S. G. Ellis, F. Herman, E. E. Loebner, W. J. Merz, C. W. Struck, and J. G. White. (*Phys. Rev.*, vol. 109, p. 1860; March 1, 1958.) Ultraviolet illumination produces photovoltages greater than the band gap in ZnS crystals grown from the vapor. The crystals contained random stacking faults.

535.215:546.482.21:538.6 2427

Surface Photoconductivity of Cadmium Sulphide Modified with Magnetic Field—S. Tanaka and T. Masumi. (*J. Phys. Soc. Japan*, vol. 13, pp. 22–32; January, 1958.) Report and discussion of measurements made on CdS single crystals.

535.37 2428

Energy Storage in ZnS and ZnCdS Phosphors—H. Kallmann and E. Sucov. (*Phys. Rev.*, vol. 109, pp. 1473–1478; March 1, 1958.) It was found that the trap concentration was of the order of $10^{15}/cm^3$ in all the phosphors examined. The observed slow rate of decay of the stored energy is explained by predominant retrapping in traps of various depths. It is concluded that the decay of stored electrons can take place radiatively and/or nonradiatively and that the rate for both processes is of the same order of magnitude. It is also shown that the light sum under a stimulation curve does not give a true picture of the trap population.

535.37 2429

Temperature Characteristics of Barium Strontium Lithium Silicate Phosphors—A. H. McKeag. (*J. Electrochem. Soc.*, vol. 105, pp. 78–81; February, 1958.) "The changes in spectral emission, efficiency, and temperature stability are discussed which result from changes in the following variable parameters in phosphor preparation: the Ba:Sr ratio, Li content, base:acid ratio, activator concentrations, and firing conditions."

535.371.07.002.2:621.397.62:535.623 2430

Photodeposition of Luminescent Screens—M. Sadowsky and P. D. Payne, Jr. (*J. Electrochem. Soc.*, vol. 105, pp. 105–107; February, 1958.) The method of deposition of the phosphor on a CRT screen for color television is described, with details of how to overcome faults which are liable to occur.

535.376 2431

The Luminescence Response of Phosphors to Low-Energy Ion Bombardment—C. F. Eve and H. E. Duckworth. (*Canad. J. Phys.*, vol. 36, pp. 104–116; January, 1958.) The response of ZnS-Ag and Zn_2SiO_2-Mn was determined as a function of the ion energy and the form of the dependence derived. Experimental results for ZnS-Ag are consistent with a theory that the bombarding particles penetrate the phosphor as neutral atoms and produce luminescence by electronic excitation.

537.221/.227:546.431.824–31 2432

Surface- and Space-Charge Effects in Ceramic Barium Titanate—W. R. Büssem and E. C. Subbarao. (*Naturwissenschaften*, vol. 44, p. 509; October, 1957.) Interim report on the results of X-ray tests on $BaTiO_2$ specimens subjected to ultraviolet radiation and to various surface treatments.

537.226/.227:546.817.824 2433

Dielectric Properties of Lead Titanate and its Solid Solutions at Low Temperature under Strong Electric Field—S. Nomura and J. Kobayashi. (*J. Phys. Soc. Japan*, vol. 13, pp. 114–115; January, 1958.)

537.226.3:621.315.616 2434

On Dielectric Absorption in Plastic Insulators—A. Kelen. (*Phys. and Chem. Solids*, vol. 2, pp. 150–151; April, 1957.)

537.226.31 2435

Motion of a Charge Parallel to the Axis of a Cylindrical Channel in a Dielectric—L. S. Bogdankevich and B. M. Bolotovskiĭ. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1421–1428; June, 1957.) The field produced by a charge moving parallel to the axis of a cylindrical channel is determined. The field and energy losses of the charge are calculated for various conditions of the medium.

537.226.31 2436

Anomalous Dispersion of Permittivity in Feldspars—V. A. Ioffe and G. I. Khvostenko. (*Doklady Akad. Nauk S.S.S.R.* vol. 118, pp. 709–712; February 1, 1958.)

537.228.1:549.514.51 2437

Theory of Plane Elastic Waves in a Piezoelectric Crystalline Medium and Determination of Elastic and Piezoelectric Constants of Quartz—I. Koga, M. Aruga, and Y. Yoshinaka. (*Phys. Rev.*, vol. 109, pp. 1467–1473; March 1, 1958.) In the case of a plane elastic wave only the component of piezoelectric polarization in the direction of wave propagation produces a restoring force against mechanical strain. Thus the elastic and piezoelectric constants can be determined from experimental data. A discrepancy between theory and experiment in the results of earlier workers [see 1452 of 1941 (Atanasoff *et al.*)] is explained.

537.228.1:549.514.51 **2438**

Anelasticity of Synthetic Crystalline Quartz at Low Temperatures—J. C. King. (*Phys. Rev.*, vol. 109, pp. 1552–1553; March 1, 1958.) "This is a preliminary report of an examination of the anelasticity and frequency-temperature behavior of synthetic quartz resonators, vibrating in thickness shear at low temperatures. The stress-induced relaxation absorption occurring at 50°K for a frequency of vibration of 5 mc in natural quartz is found to be three orders of magnitude larger in some samples of the synthetic quartz."

537.311.33 **2439**

Theory of Interstitial Impurity States in Semiconductors—P. E. Kaus. (*Phys. Rev.*, vol. 109, pp. 1944–1952; March 15, 1958.) "The ionization energy and expectation value of the radius corresponding to the states of several interstitial impurities in Ge and Si are calculated. The range of the valence electron of the impurity is divided into two regions: an inner region, which is treated microscopically, and an outer region, which is treated macroscopically. The separation radius, which is primarily a function of the host crystal, is a parameter of the calculation. At a critical separation radius a rapid change of ionization energy and wavefunction results. The calculations are carried out for several impurities in column I of the periodic table."

537.311.33 **2440**

On the Exciton Mechanism for Capture of Current Carriers in Homopolar Semiconductors—V. L. Bonch-Bruevich. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1470–1478; June, 1957.) The capture of charge carriers by structural defects with energy transfer to small-radius excitons is investigated. The probability of this transfer and the temperature dependence of the recombination coefficients are also examined.

537.311.33 **2441**

On the Mass-Action Laws in Degenerate Semiconductors—F. W. G. Rose. (*Proc. Phys. Soc. London*, vol. 71, pp. 699–701; April 1, 1958.) An analysis which defines the effective density of the energy levels in the conduction band and valence band. See also 482 of 1958.

537.311.33 **2442**

Decay Law for the Concentration of Non-Equilibrium Charge Carriers in Semiconductors—G. M. Guro. -*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 158–165; July, 1957.) The kinetics of the decay of non-equilibrium carriers in a semiconductor containing a small concentration of traps is examined. In addition to monomolecular and bimolecular modes, a constant-rate recombination is identified. This occurs at low temperature when the recombination cross-section for minority carriers is much larger than that for the majority carriers.

537.311.33 **2443**

On the Equivalence of the Fokker-Planck Method and the Free-Energy Method for the Calculation of Carrier Density Fluctuations in Semiconductors—K. M. Van Vliet. (*Physica*, vol. 23, pp. 248–252; March, 1957.) The Fokker-Planck method is applied to a semiconductor with transitions between the valence band, the conduction band, and one kind of impurity level. The results are consistent with the equations of Burgess (793 of 1956) obtained by the thermodynamic free-energy method.

537.311.33 **2444**

Electrical and Optical Properties of some $M_2{}^{Vb}N_3{}^{VIb}$ Semiconductors—J. Black, E. M. Conwell, L. Seigle, and C. W. Spencer. (*Phys. and Chem. Solids*, vol. 2, no. 3, pp. 240–251; 1957.) A number of compounds of group Vb and VIb elements, with chemical formula $M_2{}^{V}N^{b}{}_3{}^{VIb}$, have been synthesized as single crystals of fairly good purity. Experimental results are interpreted according to the usual semiconductor model. Energy gaps range from 1.7ev for Sb_2S_3 to 0.16ev for Bi_2Te_3, decreasing as the atomic number of the components increases.

537.311.33:537.29 **2445**

Influence of an External Electric Field on the Adsorption Properties of a Semiconductor—F. F. Vol'kenstein and V. B. Sandomirskiĭ. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 980–982; February 11, 1958.) A theoretical treatment to determine the variation of absorption due to a uniform electric field directed perpendicularly to the semiconductor surface.

537.311.33:546.23 **2446**

The Field-Strength Dependence of the Electrical Conductivity of Selenium Single Crystals—H. Gobrecht and H. Hamisch. (*Z. Physik.*, vol. 148, pp. 218–232; April 3, 1957.) Report on investigations of the influence of a strong alternating field on the conductivity perpendicular to the field. It is concluded that the dependence of conductivity on field strength may be explained as being due to the influence of the field on the concentration of charge carriers. See also 2447 below.

537.311.33:546.23:537.228.1 **2447**

The Piezoelectric Effect in Selenium—H. Gobrecht, H. Hamisch, and A. Tausend. (*Z. Physik.*, vol. 148, pp. 209–217; April 3, 1957.) Report on investigations of the influence of ultrasonic oscillations on the conductivity of single-crystal Se. The piezoelectric constant was determined by a dynamic as well as a quasi-static method.

537.311.33:546.24 **2448**

On the Structure of the Electron Spectrum in Lattices of the Tellurium Type—Yu. A. Firsov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1350–1367; June, 1957.) The general properties of the energy spectrum of an excess electron are studied by group-theory methods. The possibility of contact between the zone in definite directions in the **k**-space is considered and the effect of the spin-orbit interaction is examined. In semiconductors of this type there can be two kinds of carriers of the same sign.

537.311.33:546.26–1:538.21 **2449**

The Electric and Magnetic Properties of Graphite—R. R. Haering and P. R. Wallace. (*Phys. and Chem. Solids*, vol. 3, nos. 3/4, pp. 253–274; 1957.)

537.311.33:[546.28+546.289 **2450**

The Manufacture of High-Purity Germanium and Silicon Crystals—H. F. Mataré. (*Elektron Rundschau*, vol. 11, pp. 293–296; October, 1957.) Outline of some techniques used, particularly those designed to overcome the greater difficulties inherent in the purification of Si.

537.311.33:[546.28+546.289 **2451**

Tight-Bonding Calculation of Acceptor Energies in Germanium and Silicon—R. G. Shulman. (*Phys. and Chem. Solids*, vol. 2, pp. 115–118; April, 1957.) "The differences of hole ionization energies among the group-III elements acting as acceptors in silicon indicate the necessity of considering the specific contribution of the acceptor atom. Energies of two electron bonds are calculated using Morse curves to approximate interatomic potentials. The additional binding energy increases sharply from gallium to indium in accord with experiment. Arguments are presented to show why varying the acceptor element is less important in germanium."

537.311.33:546.28 **2452**

Ionization Rates for Electrons and Holes in Silicon—A. G. Chynoweth. (*Phys. Rev.*, vol 109, pp. 1537–1540; March 1, 1958.) The ionization rate for electrons is found to be higher than that for holes for the following ranges of field-strength E: for holes, $(2.5–6.0)\times 10^5$ v/cm; for electrons, $(2.0–5.0)\times 10^5$ v/cm. The results suggest that the field dependence of the ionization rate for holes and probably for electrons also, could be expressed by $a\exp(-b/E)$.

537.311.33:546.28:669.046.54/.55 **2453**

Zone Purification of Silicon—E. A. Taft and F. H. Horn. (*J. Electrochem. Soc.*, vol. 105, pp. 81–83; February, 1958.) "A procedure is described for the zone purification of high purity Si using thin-walled quartz boats. Data are given that show that improved lifetime and more uniform electrical resistivity result from the zone purification of commercially available Si."

537.311.33:546.289 **2454**

The Low-Temperature Electrical Conductivity of *n*-Type Germanium—S. H. Koenig and G. R. Gunther-Mohr. (*Phys. and Chem. Solids*, vol. 2, no. 4, pp. 268–283; 1957.) Samples of reasonably pure *n*-type Ge single crystals were investigated at temperatures between 1.8 and 5.1°K. The dominant conductivity mechanism is associated either with the conduction band or with an impurity conduction mechanism according to whether the temperature is greater or less than about 4°K. The mechanism of impurity conduction fits a model proposed by Mott (see 2088 of 1957). The conductivity of the conduction band deviates from Ohm's law at fields as low as 3 per cent of the threshold field for breakdown generally ascribed to impact ionization.

537.311.33:546.289 **2455**

Electrical Methods for Determining the Positions of Dislocation Regions in Germanium—C. A. Hogarth and A. C. Baynham. (*Proc. Phys. Soc. London*, vol. 71, pp. 647–653, plate; April 1, 1958.) In Ge crystals grown on a deformed seed, edge dislocations occur. This gives regions of high electrical conductivity in *n* and *p*-type samples. The positions of dislocacation walls determined from point-contact rectification measurements or by plotting potential against distance at constant current, agree with the positions located by etch-pit examination of the surfaces. Evidence of the *p*-type character of dislocations in *n*-type Ge is shown.

537.311.33:546.289 **2456**

The Fermi Level in Germanium at High Temperatures—J. S. Blakemore. (*Proc. Phys. Soc. London*, vol. 71, pp. 692–694; April 1, 1958.) Some results are given of calculations on the Fermi level in doped and intrinsic Ge from room temperature to 1200°K.

537.311.33:546.289 **2457**

Precipitation of Nickel and Copper from Supersaturated Solutions in Germanium—P. Penning. (*Philips Res. Rep.*, vol. 13, pp. 17–36; February, 1958.) During the anneal of Ge samples supersaturated with Ni, unidentified acceptors with a low activation energy are observed in addition to the acceptor levels arising from substitutional Ni atoms. A mechanism is suggested in which these acceptors are associated with vacancies left behind in the lattice when a substitutional Ni atom jumps to an interstitial site. The interstitial Ni atoms then diffuse rapidly to nuclei of precipitation. Copper gives rise to a similar behavior. The presence of a high density of vacancies during the precipitation of one of these elements greatly facilitates the penetration of the other, permitting concentrations much larger than the saturation value. See also 3779 of 1956.

537.311.33:546.289 2458

Generation of Imperfections in Germanium Crystals by Thermal Strain—P. Penning. (*Philips Res. Rep.*, vol. 13, pp. 79–97; February, 1958.) Thermal strain is induced in a crystal if it is heated inhomogeneously or quenched from a high temperature, the strain resulting in either plastic flow or cracking. The distribution of dislocations resulting from plastic flow shows marked characteristics which can be explained by assuming that plastic flow is proportional to the elastic strain induced by the nonuniform temperature. The sources and effects of these strains on crystals grown from a melt are discussed.

537.311.33:546.289:535.215:538.639 2459

On the Anisotropy of the Even (Transverse) Photomagnetic Effect in Germanium Single Crystals—I. K. Kikoin and Yu. A. Bykovskiĭ. (*Doklady Akad. Nauk. S.S.S.R.*, vol. 116, pp. 381–384; September 21, 1957.) Experiments carried out on a round disk-like specimen of *n*-type Ge in a magnetic field with illumination normal to the field showed that the potential difference between opposite points on the disk varied with the angle of rotation of the specimen about the axis parallel to the field. The anisotropy of the transverse photomagnetic effect in a sample with its (111) axis perpendicular to its surface is shown graphically. No correlation was found between transverse and usual photomagnetic effects. See also 491 of 1957.

537.311.33:546.289:538.569.4 2460

Cyclotron Resonance over a Wide Temperature Range—D. M. S. Bagguley, J. A. Powell, and D. J. Taylor. (*Proc. Phys. Soc. London*, vol. 70, pp. 759–762; October 1, 1957.) Cyclotron resonance experiments on Ge doped with Au were carried out at temperatures in the range 4°K to 90°K. See also 1121 of 1957 (Dexter *et al.*).

537.311.33:546.289:538.6 2461

Direct-Transition Exciton and Fine Structure of the Magneto-absorption Spectrum in Germanium—S. Zwerdling, L. M. Roth, and B. Lax. (*Phys. Rev.*, vol. 109, pp. 2207–2209; March 15, 1958.) Report of the observation of exciton absorption just below the direct gap in germanium, together with the fine structure of the related oscillatory magneto-absorption. The exciton was also studied at various magnetic field strengths.

537.311.33:546.289:538.63 2462

Magnetoresistive Phenomena in *n*-type Ge Semiconductors in Strong Magnetic Fields—M. I. Klinger and P. I. Voronyuk. (*Zh. Eksp. Teor. Fiz.*, vol. 33, pp. 77–87; July, 1957.) The equilibrium electron concentration, the Hall constant and resistivity are examined and their dependence on the magnetic field strength is discussed. The nature of the anisotropy of these quantities is determined by the anisotropy of the electron mass and by the number and mutual arrangement of the constant-energy ellipsoids.

537.311.33:546.46.284 2463

Semiconducting Properties of Mg_2Si Single Crystals—R. G. Morris, R. D. Redin, and G. C. Danielson. (*Phys. Rev.*, vol. 109, pp. 1909–1915; March 15, 1958.) A report of resistivity and Hall-effect measurements on high-purity *n* type and *p*-type Mg_2Si single crystals obtained from melts of the constituents. The *p*-type crystals were obtained by doping the melt with silver or copper. The room-temperature Hall mobilities were 406 $cm^2/vsec$ for *n*-type and 56 $cm^2/vsec$ for *p*-type material. Carrier concentrations in the saturation region were as low as 8×10^{16} cm^{-3} for *n*-type and 4×10^{17} cm^{-3} for *p*-type samples.

537.311.33:546.46.289 2464

Semiconducting Properties of Mg_2Ge Single Crystals—R. D. Redin, R. G. Morris, and G. C. Danielson. (*Phys. Rev.*, vol. 109, pp. 1916–1920; March 15, 1958.) A report of resistivity and Hall-effect measurements on single crystals of Mg_2Ge obtained from melts of the constituents. Undoped crystals which were *n*-type had saturated impurity concentrations as low as $3\times10^{15}cm^{-3}$; silver-doped crystals were *p*-type and had saturated impurity carrier concentrations roughly proportional to the amount of added silver. Room-temperature Hall mobilities were 280 $cm^2/vsec$ for electrons and 110$cm^2/vsec$ for holes.

537.311.33:546.682.86 2465

Properties of *p*-type Indium Antimonide: Part 1—Electrical Properties—C. Hilsum and R. Barrie. (*Proc. Phys. Soc. London*, vol. 71, pp. 676–685; April 1, 1958.) The variation of Hall coefficient and resistivity with applied magnetic field is used to calculate the dependence of electron and hole mobilities on carrier concentration. The decrease of electron mobility with acceptor concentration is explained in terms of polar scattering and electron-hole scattering.

537.311.33:546.682.86:537.312.9 2466

Piezoresistance Constants of *P*-Type InSb—A. J. Tuzzolino. (*Phys. Rev.*, vol. 109, pp. 1980–1987; March 15, 1958.) The change of resistance in uniaxial tension was measured for several single-crystal specimens of *p*-type InSb over the range 77°–350°K. The piezoresistance coefficients were found to depend on impurity concentrations. The elasto-Hall constant was measured at 77°K for the purest specimens and the experimental results indicate that, in the extrinsic range, the large piezoresistance is primarily due to stress-induced changes in the tensor mobility of the holes. It is concluded that the valence band extrema occur at, or very near, $\mathbf{K}=0$ in the Brillouin zone with energy surfaces similar to those of Si and Ge.

537.311.33:546.682.86:537.32 2467

Electron Scattering in InSb—H. Ehrenreich. (*Phys. and Chem. Solids*, vol. 2, pp. 131–149; April, 1957.) The effects of electron scattering by acoustical and optical phonons as well as electron-hole scattering on the mobility and thermoelectric power of intrinsic InSb are considered using the conduction band theory of Kane (*ibid.*, vol. 1, pp. 249–261; January, 1957). Good agreement is found between theory and experiment for both mobility and thermoelectric power.

537.311.33:546.682.86:537.32 2468

On the Scattering of Electrons by Optical Modes in Indium Antimonide—M. Rodot. (*C. R. Acad. Sci., Paris*, vol. 245, pp. 1051–1054; September 23, 1957.) Measurements of the magneto-thermoelectric effect and the Nernst effect in specimens of *n*-type InSb at various temperatures gave results in accordance with the theory of polar scattering. See also 3772 of 1956.

537.311.33:546.682.86:539.23 2469

Resistivity and Hall Effect of Thin Films of Indium Antimonide—J. Launey and A. Colombani. (*C. R. Acad. Sci., Paris*, vol. 245, pp. 1009–1011; September 16, 1957.) Films were reheated and then cooled to room temperature before tests were made. Hall effect was found to increase with reheat temperature and to be strictly proportional to current intensity. Consistent results were not obtained if the reheat temperature was above 470°C. Resistivity decreased rapidly with increase in film thickness.

537.311.33:546.682.86:539.23 2470

Hall Effect and Magnetoresistance of Thin Films of Indium Antimonide—J. Launey. (*C. R. Acad. Sci., Paris*, vol. 245, pp. 1122–1124; September 30, 1957.) See also 2469 above.

537.311.33: [546.873.241+546.863.241+546.193.241 2471

Preparation and some Physical Properties of Bi_2Te_3, Sb_2Te_3 and As_2Te_3—T. C. Harman, B. Paris, S. E. Miller, and H. L. Goering. (*Phys. and Chem. Solids*, vol. 2, no. 3, pp. 181–190; 1957.) The preparation of the above intermetallic compounds from purified elements by several techniques is discussed. Electrical and thermal properties are presented as functions of temperature and impurity concentration. The variation of carrier mobility with temperature is approximately $T^{-5/2}$ for As_2Te_3 and Bi_2Te_3.

537.311.33:546.873.241:537.323 2472

The Electrical Conductivity and Thermoelectric Power of Bismuth Telluride—H. J. Goldsmid. (*Proc. Phys. Soc., London*, vol. 71, pp. 633–646; April 1, 1958.) The electrical conductivity and thermoelectric power of Bi_2Te_3 are measured over a range of temperatures and for *n*-type and *p*-type samples. This gives the fundamental semiconductor parameters. Samples show extrinsic conduction and partial degeneration over parts of the temperature range necessitating the use of Fermi-Dirac statistics in interpretation of the results.

537.311.33:621.314.63 2473

Electrical Breakdown in *p-n* Junctions—A. G. Chynoweth. (*Bell Lab. Rec.*, vol. 36, pp. 47–51; February, 1958.) The sudden breakdown which occurs when an increasing reverse voltage is applied to a *p-n* junction is explained by the creation of free electrons and holes in an avalanche process.

538.22 2474

Thermodynamic Theory of "Weak" Ferromagnetism in Antiferromagnetic Substances—I. E. Dzyaloshinskiĭ. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1547–1562; June, 1957.) This type of ferromagnetism is attributed to relativistic spin-lattice interaction and magnetic dipole interaction. The dependence of the properties of these substances on the magnetic symmetry of the crystal is examined and the effect of an external magnetic field is also considered.

538.22 2475

Solid Solutions between Ferromagnetic and Antiferromagnetic Compounds with NiAs Structure—F. K. Lotgering and E. W. Gorter. (*Phys. and Chem. Solids*, vol. 3, nos. 3/4, pp. 238–249; 1957.) The aim of the investigation is to see whether continuous series of mixed crystals between a ferromagnetic and an anti-ferromagnetic binary compound with NiAs structure exist, and to study the magnetic properties. Several solid solutions were prepared. Saturation magnetizations were measured between 20°K and the Curie temperatures, and susceptibilities between Curie temperatures and 850°–1100°K. Results are discussed.

538.22:537.3 2476

Electrical Properties of $FeTiO_3$-Fe_2O_3 Solid Solution Series—Y. Ishikawa. (*J. Phys. Soc. Japan*, vol. 13, pp. 37–42; January, 1958.) The dc electrical conductivity and Seebeck voltage of the synthesized solid solution $x\text{FeTiO}_3\cdot(1+x)\text{Fe}_2\text{O}_3$ of ilmenite ($FeTiO_3$) and hematite (Fe_2O_3) have been measured for a composition range of $1\geq x\geq 0.33$, over a range of temperature. Both ordered (ferrimagnetic) and disordered (antiferromagnetic) specimens with the same composition were investigated. See also 1199 of 1958 (Ishikawa and Akimoto).

538.221 2477

Temperature Dependence of Ferromagnetic Anisotropy—W. J. Carr, Jr. (*Phys. Rev.*, vol.

109, pp. 1971–1976; March 15, 1958.) It is shown that Zener's result for Fe may be derived from molecular field theory. In Co a satisfactory agreement with experiment is obtained by using Zener's results together with the postulate that the intrinsic anisotropy varies with the thermal expansion in the manner recently calculated (1389 of 1958). For Ni the temperature dependence of K_1 seems to require, in addition to the tenth power of the magnetization, a multiplicative factor that is linear with temperature.

538.221 2478

Contribution to the Clarification of the Magnetic After-Effect due to Electron Diffusion in Ferrites—A. v. Kienlin. (*Z. angew. Phys.*, vol. 9, pp. 245–250; May, 1957.) On the basis of measurements an interpretation is derived of the Richter effect observed in stoichiometric Ni-Zn ferrites. See, *e.g.*, 2041 of 1953 (Feldtkeller and Sorger).

538.221:537.533.73 2479

Investigation of Ferromagnetic Substances by Electron Diffraction—S. Yamaguchi. (*Z. Metallk*, vol. 49, pp. 52–54; January, 1958.) An electron beam penetrating a ferromagnetic substance is polarized. This effect can be used to obtain a crystallographic and a magnetochemical analysis of the material.

538.221: [621.318.124+621.318.134 2480

Convention on Ferrites—(*Proc. IEE*, pt. B, vol. 104, Suppl. no. 7, pp. 399–570; 1957.) The following papers were included among those read at the IEE Convention held in London October 29–November 2, 1956. See also 1479 of 1958.

Square-Loop Materials:

1) **The Influence of Chemistry on B/H Loop Shape, coercivity and Fluk-Reversal Time in Ferrites**—J. B. Goodenough. (pp. 400–411.)

2) **Ordering in Cobalt-Ferrous Ferrites**—H. P. J. Wijn, H. van der Heide, and J. F. Fast. (pp. 412–417.)

3) **Square-Loop Ferrites obtained by Magnetic Annealing of New Compositions**—E. W. Gorter and C. J. Esveldt. (pp. 418–421.)

4) **Pulse-Response Properties of Rectangular-Loop Ferrites**—H. P. J. Wijn and H. van der Heide. (pp. 422–427.)

5) **Ferrites with Constructed Loops and Thermal Magnetic Treatment**—O. Eckert. pp. 428–432. Discussion, pp. 433–435.)

Square Loop Applications:

6) **A Magnetic-Core Matrix Store with Direct Selection using a Magnetic-Core Switch Matrix**—W. Renwick. (pp. 436–444.)

7) **The Magnetic Cell: A New Circuit Element**—D. S. Ridler and R. Grimmond. (pp. 445–456.)

8) **A Matrix Store for Data Rate Conversion**—C. J. Quartly, A. L. Cain, and R. W. Clarke. (pp. 457–463.)

9) **A Ferrite-Core Switch Matrix for Magnetic-Recording-Head Selection**—D. W. Willis. (pp. 464–469.)

10) **A 1000-Channel Neutron Velocity Spectrometer using Ferrite Data Storage**—F. H. Wells and J. G. Page. (pp. 470–480.)

11) **A Digital Computer based on Magnetic Circuits**—B. Bambrough. (pp. 485–490.)

12) **Some Applications of Square-Loop Ferrite Cores in Telecommunication Switching Circuits**—W. Six and R. A. Koolhof. (pp. 491–501.)

13) **The Application of Square-Loop Ferrite Material in Data-Processing Systems**—E. P. G. Wright. (pp. 502–511.)

14) **A Core/Transistor Logical Element**—D. Eldridge and P. F. Dorey. (pp. 512–522. Discussion, pp. 481–482, 523–522.)

Radio and Television Applications:

15) **Some Current and Future Applications for Ferrite Components in Radio and Television Receivers**—V. A. Jones and G. Campbell. (pp. 526–533.)

16) **The Application of Soft Magnetic Ferrites in Television Receiver Line-Scanning Circuits**—R. H. C. Morgan. (pp. 534–537. Discussion, pp. 538–540.)

Carrier-Frequency Applications:

17) **Ferrites Applied to Carrier-Frequency Equipment**—W. F. Glover and S. E. Buckley. (pp. 541–549.)

18) **Ferrites for Magnetic and Piezomagnetic Filter Elements with Temperature-Independent Permeability and Elasticity**—C. M. van der Burgt. (pp. 550–557.) See also 2232 and 3566 of 1957.

19) **Practical Applications and Measurements on Ferrite Electromechanical Transducers**—G. Bradfield. (pp. 558–563.)

20) **Examples of Electric Wave Filters using Ferrite Inductors**—W. Saraga. (pp. 564–567. Discussion, pp. 568–570.) See also 2047 of 1957.

538.221:621.318.124 2481

Uniaxial Anisotropy in Iron-Cobalt Ferrites—S. Iida, H. Sekizawa, and Y. Aiyama. (*J. Phys. Soc. Japan*, vol. 13, pp. 58–71; January, 1958.) The uniaxial anisotropy induced by magnetic annealing in both single-crystal and polycrystal line specimens has been studied experimentally. The magnitudes of the anisotropy depend essentially on the degree of oxidation of the specimens and become almost zero after deoxidizing heat treatments.

538.221:621.318.134 2482

Modern Applications of Ferrites—F. Mayer. (*Rev. gén. Élect.*, vol. 66, pp. 333–339; June, 1957.) A review of the properties and applications of spinel-type ferrites.

538.221:621.318.134:538.569.4 2483

Determination of the Gyromagnetic Ratio and the Magnetic Resonance Damping Coefficient of Ferrites—H. G. Beljers. (*Philips Res. Rep.*, vol. 13, pp. 10–16; February, 1958.) Methods of deriving the g factor and damping coefficient from the results of resonance measurements on polycrystalline ferrite spheres in a microwave cavity with a linearly polarized magnetic field are described. Results for three specimens are tabulated.

538.221:621.318.2 2484

The Development of Alnico Magnets containing Copper and/or Titanium up to their Present Level of Quality—W. Zumbusch. (Z. Metallk, vol. 49, pp. 1–8; January ,1958.)

538.569.4.029.64 2485

Microwave Absorption in Methyl Halides—Krishnaji and G. P. Srivastava. (*Phys. Rev.*, vol. 109, pp. 1560–1563; March 1, 1958.) It is confirmed that the absorption of 3-cm waves in methyl chloride and methyl bromide is entirely due to the inversion transition at zero wave number. In the J band the additional absorption observed is assigned to the resultant effect of various rotational transitions of the molecule.

538.632:546.3-1'48'46 2486

Variation of the Hall Coefficient of Mg-Cd Superlattice Alloys with Degree of Order—K. Yonemitsu and T. Sato. (*J. Phys. Soc. Japan*, vol. 13, pp. 15–22; January, 1958.) The temperature dependence of the Hall coefficient has been measured for Mg_3Cd, MgCd, and $MgCd_3$. At the order-disorder transformation temperature the Hall coefficient and electrical resistivity are discontinuous in opposite directions. It is considered that the change of Brillouin zone structure on transformation is responsible for the discontinuities.

538.632:546.59 2487

Hall Effect and Susceptibility of Gold—N. E. Alekseevskii and Yu. P. Gaidukov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1589–1591; June. 1957.) Tests were made on two samples of Au with differing resistivity/temperature characteristics. See also 3216 of 1957.

MEASUREMENTS AND TEST GEAR

621.3.018.41(083.74):621.373.42.029.64 2488

S.H.F. Frequency Standard uses Double Conversion—M. C. Thompson, Jr., M. J. Vetter, and D. M. Waters. (*Electronics*, vol. 31, pp. 100–101; April 11, 1958.) A harmonic from a stable crystal oscillator is mixed with a klystron output. The beat frequency is compared with another crystal-controlled frequency and a correction voltage applied to the klystron. See also 2874 of 1955 (Peter and Strandberg).

621.3.018.41(083.74):621.373.421.14 2489

An Atomic Reference Oscillator—M. P. G. Capelli, (*Brit. Commun. Electronics*, vol. 5, pp. 100–102; February, 1958.) "One of the spectrum lines of the caesium atom is used as the final frequency reference of a highly stable and accurate frequency source."

621.3.018.41(083.74):621.396.11.019.45 2490

Phase Variations of 16-kc/s Transmissions from Rugby as Received in New Zealand—Crombie, Allan, and Newman. (See 2523.)

621.314.7.001.4(083.74) 2491

I.R.E. Standards on Solid-State Devices: Methods of Testing Point-Contact Transistors for Large-Signal Applications, 1958—(PROC. IRE, vol. 46, pp. 878–888; May, 1958.) Standard 58 IRE 28. S1.

621.317.2:621.373.4 2492

A Precision Microwave Signal Generator—F. W. Cook. (*A.T.E.J.*, vol. 14, pp. 2–10; January, 1958.) Description and circuit details of an instrument covering the frequency range 580–1220 mc with automatic control of output level and provision for CW or square-wave, pulse, or sine-wave modulated output.

621.317.3:537.311.33:537.323 2493

Apparatus for Measurement of Thermal E.M.F. in Semiconductors—J. C. Brice and H. C. Wright. (*J. Sci. Instrum.*, vol. 35, pp. 146–147; April, 1958.)

621.317.3:621.314.7 2494

An Investigation of the Current Gain of Transistors at Frequencies up to 105 Mc/s—F. J. Hyde and R. W. Smith. (*Proc. IEE*, pt. B, vol. 105, pp. 221–228; May, 1958.) Apparatus is described for direct measurement of short-circuit current gain. Results obtained with commercial alloy-junction and surface-barrier transistors are presented, with corrections to give the internal diffusion-current gain, and the effect of stray capacitances on the measurements are considered. The cut-off frequency of the internal current gain is compared with values obtained indirectly from other measurements. The behavior of alloy-junction transistors agrees closely with existing one-dimensional diffusion theory while surface-barrier transistors show less agreement.

621.317.3:621.314.7:621.375.1.024 2495

Use of Operational Amplifiers in the Measurement of Transistor Parameters—W. C. Hazel. (*Rev. Sci. Instrum.*, vol. 29, pp. 235–237; March, 1958.) Methods of measuring the resistance parameters and the current amplification factor are described. Schematic circuit diagrams are included.

621.317.3:621.396.67:621.397.62 2496

Measuring TV Aerial Performance—Strafford. (See 2296.)

621.317.3:621.396.822:621.396.41 2497

The White-Noise Method of Measuring Crosstalk and Noise Interference in Multichannel Telephone Link System—J. F. Golding. (*Electronic Eng.*, vol. 30, pp. 349–351; May, 1958.) Description of the method with details of a commercially available test set.

621.317.32 2498

Measurement of Peak Values of Periodic High Voltages in a Steady State—J. Lagasse, R. Lacoste, and G. Giralt. (*Rev. gén. Élect.*, vol. 66, pp. 307–324; June, 1957.) The design and construction of a standard variable capacitor is described and the merits of different types of rectifier are discussed. See 1851 of 1957 (Lagasse and Giralt).

621.317.33:538.632 2499

A Method of Measuring Specific Resistivity and Hall Effect of Disks of Arbitrary Shape—L. J. van der Pauw. (*Philips Res. Rep.*, vol. 13, pp. 1–9; February, 1958.) The method is based on a theorem applicable to a flat specimen of arbitrary shape if the contacts are sufficiently small and located at its circumference; the disk must be free of holes.

621.317.341:621.374.015.7 2500

Sensitive Measurements of Pulse-Amplifier Gain—K. A. McCollom, D. R. deBoisblanc, and J. B. Thompson. (*Nucleonics*, vol. 16, pp. 74–76, 78; January, 1958.) The design of an amplifier comparator is described. Gain stability can be checked to within 0.01 per cent, and amplitude stability of two pulse generators can be compared to within 0.02 per cent.

621.317.35:621.391 2501

The Measurement of Power Spectra from the Point of View of Communications Engineering: Parts 1 and 2—R. B. Blackman and J. W. Tukey. (*Bell Sys. Tech. J.*, vol. 37, pp. 185–282; January, 1958, and pp. 485–569; March, 1958.) A comprehensive mathematical and statistical study is presented, with details of anlaysis and planning for measurement. The analysis is then reconsidered in greater detail and from alternative points of view. Over 50 references.

621.317.361:538.569.4:539.1.08 2502

Measurement and Control of Microwave Frequencies by Lower Radio Frequencies—R. C. Mackey and W. D. Hershberger. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-5, pp. 64–68; January, 1957. Abstract, PROC. IRE, vol. 45, p. 576; April, 1957.)

621.317.411 2503

The Determination of the Permeability of Ferromagnetic Materials from the Thermal Noise Voltage of Coils—W. Nonnenmacher and L. Schweizer. (*Z. angew. Phys.*, vol. 9, pp. 239–245; May, 1957.) The complex permeability is measured as a function of frequency without the use of an externally applied alternating field. The thermal fluctuations in the ferromagnetic core material give rise to a noise voltage across the test coil. Results obtained agree well with those from conventional bridge measurements at low field strengths.

621.317.42:621.395.625.3 2504

The Determination of the Magnetization of Magnetic Recording Tape—O. Schmidbauer. (*Elektron Rundschau*, vol. 11, pp. 302–305; October, 1957.) The magnetization of tape is best defined on the basis of short-circuit flux measurements; a suitable method is described. The determination of transverse magnetization, where it is undesirable or where it is used for synchronizing purposes, and the calibration of heads used in such measurements are also discussed. A specially designed electronic fluxmeter is briefly detailed.

621.317.44 2505

Adaptation of the Iliovici Permeameter to the Investigation of Hypermagnetic Materials—L. Garde. (*Rev. gén. Élect.*, vol. 66, pp. 375–379; July, 1957.) To reduce the error of the instrument which can be excessive in measurements on samples of high permeatility, the second yoke is constructed of mumetal.

621.317.715:621.375.024 2506

Device for Matching a Galvanometer or D.C. Indicator to its Associated Circuit—T. M. Dauphinee. (*Rev. Sci. Instrum.*, vol. 29, pp. 240–241; March, 1958.) "Impedance matching is achieved by use of a chopper and transformer circuit which permits near optimum use of the available power."

621.317.727:621.316.93:621.314.63 2507

Silicon Diodes as Protective Meter Shunts—A. S. Penfold and E. L. Garwin. (*Rev. Sci. Instrum.*, vol. 29, pp. 252–253; March, 1958.) Relies on the very small current through the diode for forward voltages less than 0.5 volt.

621.317.733 2508

Impedance Bridges—J. F. Golding. (*Brit. Commun. Electronics*, vol. 5, pp. 104–109; February, 1958.) "After a short discussion of impedance, various types of impedance bridge and their applications are described. A table gives brief specifications of representative bridges available in Britain."

621.317.755 2509

Modern Oscilloscope Practice—(*Electronic and Radio Engr.*, vol. 35, pp. 212–225; June, 1958.) A review of instruments manufactured in the U. K., with simplified circuits of various parts, showing how particular facilities are provided. Oscilloscope cameras are discussed briefly.

621.317.755:621.385.832 2510

Broadband Oscilloscope Tube—D. J. Brangaccio, A. F. Dietrich, and J. W. Sullivan. (*Bell. Sys. Tech. J.*, vol. 37, pp. 447–460; March, 1958.) The design and operation of a special oscilloscope tube is described. Traveling-wave tube principles are applied to the design of a helix-type vertical deflection system to give a flat bandwidth characteristic over 600 mc. Novel features are the particular deflection system and a trace on the screen which is readable without other optical means. The construction is similar to commercial tubes except for closer tolerance in electrode alignment. Repetitive pulses a few millimicroseconds in width can be viewed directly.

621.317.784.029.63 2511

U.H.F. Power Meter for Operation in the 200-Mc/s Communication Band—J. K. Murray. (*Electronic Eng.*, vol. 30, pp. 345–348; May, 1958.) Description of the design of a direct-reading power meter for the frequency range 1700–2300 mc.

621.317.794:621.319.4 2512

Notes on Capacitance Bolometers—H. J. Albrecht. (*Proc. IRE, Aust.*, vol. 18, pp. 128–129; April, 1957.) Note on the principles and design of an instrument comprising temperature-sensitive capacitors, with $BaTiO_3$ or $SrTiO_3$ dielectric, in two tuned circuits.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

621.365.5 2513

Induction Heating of Ferromagnetic Samples at Stepped Frequencies—J. Minssieux. (*Rev. gén. Élect.*, vol. 66, pp. 239–245; May, 1957.) In the case of steel rods for example, 50-cps ac may be used for heating up to 700°C, and 1000-cps ac for heating from 700°C to 1250°C.

621.38:62 2514

Electronics in Heavy Industry—G. M. Ettinger. (*Elect. Rev. London.*, vol. 162, pp. 30–35; January 3, 1958.) Survey of applications in measurement, control, data handling, and processing.

621.384.612 2515

About Damping and Antidamping Betatron Oscillations, taking into account Non-Adiabatic Properties of the Radiation—A. N. Matveev. (*Nuovo Cim.*, vol. 6, pp. 1296–1304; December 1, 1957.) (In English.) An analysis of betatron oscillations in high-energy electron synchrotrons shows that damping and antidamping effects would only occur if radiation were an adiabatic process.

621.384.612 2516

Electron Motion in Synchrotrons in the Presence of Radiation—A. N. Matveev. (*Nuovo Cim.*, vol. 6, pp. 1305–1317; December 1, 1957.) (In English.) A stochastic theory of betatron and phase oscillations induced by radiation fluctuations is presented. See also 240 of 1957.

621.387.424 2517

Influence of the Effective Length and Diameter of the Cylinder on the Plateau Characteristic of Externally Graphited Glass-Walled Geiger-Müller Counters—D. Blanc. (*Nuovo Cim.*, vol. 6, pp. 974–976; October 1, 1957.) (In French.)

PROPAGATION OF WAVES

621.396.11 2518

On the Theory of Propagation of Electromagnetic Waves Along a Curved Surface—J. R. Wait. (*Canad. J. Phys.*, vol. 36, pp. 9–17; January, 1958.) The case of vertically polarized waves propagated across a discontinuity in curvature and electrical properties is considered. An approximate expression is derived for the mutual impedance between two antennas on either side of the boundary by using the principle of stationary phase and the concept of surface impedance. The first-order effects of the boundary changes are shown to be additive corrections to the mutual impedance for a homogeneous surface.

621.396.11 2519

Some Methods for Studying Wave Propagation in a Uniform Magneto-ionic Medium—V. A. Bailey. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 118–125; 1958.) The Appleton-Hartree expression for complex refractive index can be simplified by using the approximations:

$$(1+s^2)^{1/2}=(4+3s^2)/(4+s^2)$$

$$\text{or}=s(4s^2+3)/(4s^2+1).$$

The resulting expressions have errors of less than 1 per cent except under limited sets of conditions.

621.396.11:551.510.535 2520

The Distance Attenuation of Radio Waves Reflected at Vertical Incidence from the Ionosphere—J. D. Whitehead. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 150–152; 1958.) "It is shown that the assumption that the amplitude of radio waves propagated from a point source falls off inversely as the group path P' leads to a value of apparent reflection coefficient of the ionosphere which may be seriously in error, and in particular to a large error in the measurement of the electronic collision frequency in the F region."

621.396.11.029.4(204) 2521

On Communication in the Sea by V. L. F. Electromagnetic Waves—K. Furutsu. (*J. Radio Res. Labs. Japan*, vol. 5, pp. 19–33; January 1958.) A theoretical analysis of the various modes of propagation when either transmitter or receiver or both are immersed shows that a horizontal magnetic bar is the most suitable radiator for use under the sea. Numerical values of input impedance and induced voltage are given for such a radiator under transmitting and receiving conditions. Field-strength curves are presented for various conditions of communication from sea to atmosphere or in the sea.

621.396.11.029.45 2522

Differences Between the East-West and West-East Propagation of V.L.F. Signals over Long Distances—D. D. Crombie. (*J. Atmos. Terr. Phys.*, vol. 12, nos. 2/3, pp. 110–117; 1958.) Early suggestions that eastward traveling waves are less attenuated than those of the opposite sense are supported by recent measurements. Such an effect might be due to the propagation of TM modes in the presence of free electrons in the waveguide formed by the ionosphere and the earth. Propagation along the earth's magnetic field (N–S) would obey the reciprocity law while in E-W directions it would not.

621.396.11.029.45:621.3.018.41(083.74) 2523

Phase Variations of 16-kc/s Transmissions from Rugby as Received in New Zealand—D. D. Crombie, A. H. Allan, and M. Newman. (*Proc. IEE*, pt B, vol. 105, pp. 301–304; May, 1958.) It is suggested that the measured diurnal phase changes over the 19,000 km path can be explained to a first approximation by a model in which both earth and ionosphere are considered as perfectly conducting sheets whose separation varies from night to day. See also 1482 of 1956 (Allan *et al.*).

621.396.11.029.6:621.396.81 2524

Approximate Methods for the Evaluation of the Field Strength of Ultra Short Radio Waves taking Account of the Influence of the Local Ground Profile—A. I. Kalinin. (*Radiotekhnika, Mosk.*, vol. 12, pp. 13–23; April, 1957.) Interference formulas are used for field strength calculations for unobstructed paths. Where screening occurs the obstacles are represented approximately by spheres of a radius depending on the nature of the obstacle. Formulas for attenuation factor, angle of diffraction, and refraction coefficient are derived.

621.396.11.029.62:551.510.535 2525

Off-Path Propagation at V.H.F.—V. C. Pineo. (Proc. IRE, vol. 46, p. 922; May, 1958.) Reception of signals propagated by ionospheric forward scatter at two points about 6½ degrees to each side of the main transmitted beam shows the influence of meteoric ionization.

621.396.11.029.63/.64 2526

Microwave Line-of-Sight Propagation—M. W. Gough. (*Electronic Eng.*, vol. 30, pp. 237–247; May, 1958.) A survey of some fundamental investigations made at frequencies above 300 mc, mainly since 1939, in Europe and the U.S.A. Effects of ground reflection are discussed together with the use of passive reflectors and screens. Fading mechanisms and diurnal and seasonal variations in fading due to weather conditions are considered. Forty-five references.

621.396.11.029.63/.64:551.510.52 2527

Tropospheric Scatter Propagation—G. Millington. (*Electronic Eng.*, vol. 30, pp. 248–252; May, 1958.) "The physical mechanisms of long-distance propagation are reviewed with special reference to forward scattering. Recent research in the United Kingdom is described on the nature of the signal variations and their relation to meteorological conditions. The use of scatter links for wide-band systems is discussed, including the problems of aircraft reflections and mutual interference due to frequency sharing."

621.396.11.029.63/.64:551.510.52 2528

Tropospheric Scatter Communication—G. L. Grisdale. (*Electronic Eng.*, vol. 30, pp. 272–275; May, 1958.) Tropospheric scatter can give reliable communication where terrain limits multihop microwave links, but the rapid fading characteristic and limited signal strength over the longer distances impair quality. The principal features and application of this method of propagation are considered.

RECEPTION

621.376.232:621.396.822 2529

The Behaviour of Phase-Sensitive Detectors—M. B. Palma-Vittorelli, M. U. Palma, and D. Palumbo. (*Nuovo Cim.*, vol. 6, pp. 1211–1220; November 1, 1957.) (In English.) An analysis is made of the output of different types of phase detector for any given input, and expressions are given for the frequencies present in the output.

621.396.62:629.19 2530

Microlock—H. L. Richter, Jr. (*QST*, vol. 41, pp. 20–24; December, 1957.) Details are given of a receiver for tracking and receiving telemetry signals from earth satellites, using a phase-locked loop system with very narrow bandwidth, and designed for the reception of signals below the noise threshold of conventional receivers.

621.396.621.54:621.372.632:621.373.51 2531

Crystal Converter for Tropo-Scatter Receivers—P. Gruber. (*Electronics*, vol. 31, pp. 78–82; April 11, 1958.) A noise-figure improvement of 0.5–1.5 db has been obtained at frequencies of 1–2 kmc by replacing a RF amplifier by a Type-1N21E silicon diode in a suitably designed coaxial mixer.

621.396.8 2532

Carrier-to-Noise Statistics for Various Carrier and Interference Characteristics—K. K. Clarke and J. Cohn. (Proc. IRE, vol. 46, pp. 889–895; May, 1958.) "Techniques are presented for the calculation of the statistical properties of the resultant carrier-to-noise ratios of systems subject to both additive and multiplicative noise. The cases considered are those in which the desired signal is either steady or exhibits Rayleigh fading while the interference consists of receiver noise plus an interfering signal which may be steady, Rayleigh fading, Gaussian fading, or Rayleigh fast fading with slow Gaussian fading of the median of the Rayleigh distribution. The results of the indicated calculations are presented graphically."

621.396.812.3:621.396.666 2533

Theoretical Diversity Improvement in Frequency-Shift Keying—J. N. Pierce. (Proc. IRE, vol. 46, pp. 903–910; May, 1958.) If prior information about signal amplitude and phase is not available, square-law combination is the optimum system; if the information is available, coherent combination and detection are the optimum, giving a 3-db improvement in the error probability at low probabilities.

621.396.822:551.594.6 2534

Atmospheric Radio Noise at Frequencies between 10 kc/s and 30 kc/s—Harwood. (See 2421.)

621.396.822:[621.314.632-71+621.396.67-71
2535

Cooling of Microwave Crystal Mixers and Antennas—G. C. Messenger. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 62–63; January, 1957. Abstract, Proc. IRE, vol. 45, p. 576; April, 1957.)

621.396.823 2536

Contribution to the Prediction of Radio Interference Capacity of Very-High-Voltage Lines—J. Meyer de Stadelhofen and W. Walter. (*Tech. Mitt. PTT*, vol. 35, pp. 456–479; November 1, 1957.) (In French and German.) The characteristics of corona effects and the reduction of corona by the use of stranded conductors are described. Details are given of measurements carried out near power lines and on insulators and lines in a laboratory to determine the attenuation of the interference field perpendicular to and along the lines, and to assess the usefulness of laboratory tests in predicting the level of interference due to power lines under various atmospheric conditions.

STATIONS AND COMMUNICATION SYSTEMS

621.376:621.396.5 2537

Selection of Modulation for Speech Communication—G. J. Kelley. (*Electronics*, vol., 31, pp. 56–58; March 28, 1958.) The type used (am, fm, SSB, or DSB suppressed-carrier) can be chosen by a logical evaluation. The factors compared for particular applications include signal-noise performance, distortion, and stability.

621.391 2538

Error Rates in Data Transmission—S. Reiger. (Proc. IRE, vol. 46, pp. 919–920; May, 1958.) Error rate reduction using correcting codes and binary signaling is compared with the gain obtained using other forms of signaling such a quantized FM.

621.391:621.3.018.75 2539

A Statistical Description of Coincidences among Random Pulse Trains—S. Stein and D. Johansen. (Proc. IRE, vol. 46, pp. 827–830; May, 1958.) The derivation of the statistical distribution of the coincidence durations may be reduced to the problem of finding the probability of occurrence of a coincidence at any instant between trains of randomly occurring pulses with a known pulse length distribution.

621.391:621.3.018.78 2540

Characteristics of Signal Transmission and Distortion—R. Possenti. (*Note Recensioni Notiz.*, vol. 6, pp. 639–667; September/October, 1957.) The concepts of group velocity and phase distortion are discussed and a method of evaluating signal distortion is derived.

621.391:621.397.2 2541

Statistical Encoding for Text and Picture Communication—W. S. Michel. (*Commun. and Electronics*, no. 35, pp. 33–36; March, 1958.) An investigation of the channel capacity required for various types of black and white copy based on one-dimensional differential coordinates with statistically matched encoding. A binary digital transmission channel is assumed.

621.396.2.029.631.64 2542

A Survey of Microwave Radio Communication—W. J. Bray. (*Electronic Eng.*, vol. 30, pp. 226–236; May, 1958.) "This article is a broad survey of line-of-sight and tropospheric forward-scatter radio communication systems operating in the frequency range from about 1000 to 10,000 mc, for the transmission of multichannel telephony and television signals. The applications of such systems, the transmission requirements, the factors determining the choice of frequency, and the basic equipment techniques are described. Possible future developments are also considered."

621.396.32:621.396.812.3 2543

Measurement of Fading Margin in V.H.F. Radio Teletype Circuits—K. Kawakami and H. Akima. (*J. Radio Res. Labs. Japan*, vol. 5, pp. 1–18; January, 1958.) "Fading margin" is defined as the ratio of signal strength with fading to that without fading for the same signal/noise ratio. A method of measuring this quantity is described and results obtained with three different teletype VHF circuits are presented. It is concluded that knowledge of the quantity facilitates the design of communication circuits and enables the noise and fading susceptibility of various systems to be compared.

621.396.41 2544

Wide-Band Ultra-high-Frequency Over-the-Horizon Equipment—R. A. Felsenheld, H. Havstad, J. L. Jatlow, D. J. LeVine, and L. Pollack. (*Commun. and Electronics*, no. 35, pp. 86–93; March, 1958.) A description of wide-band equipment for use in toll-quality multichannel telephone or television circuits in the frequency range 680–900 mc. The receivers can be used for dual or quadruple diversity by combining the signals at the 70–mc intermediate frequency.

621.396.41:621.376.3:621.396.813 2545

Distortion in Frequency-Division Multiplex F.M. Systems due to an Interfering Carrier—R. G. Medhurst, E. M. Hicks, and W. Grossett. (*Proc. IEE*, pt B, vol. 105, pp. 282–292; May, 1958.) It is found that the distortion generated in a particular channel is accurately proportional to the relative level of the interfering carrier. Thus it is possible to plot curves of distortion in the worst channel against frequency separation of wanted and unwanted carriers; a permissible level of interfering carrier may be deduced. Numerical results are shown for various carrier frequency separations that arise under the CCIR frequency plan for 6 RF channels each carrying 600 speech channels. Provided the frequency separation is less than 9 mc the theory is in good agreement with experiment. See also 4005 of 1957 (Medhurst and Hodgkinson).

621.396.41:621.396.65 2546

The Miami-Havana Radio System and its Integration into the Telephone Networks—K. P. Stiles, F. G. Hollins, E. T. Fruhner, and W. D. Siddall. (*Commun. and Electronics*, no. 35, pp. 94–96; March, 1958.) A description of a system developed for radio and television facilities, its method of operation, and the results obtained.

621.396.41:621.396.822:621.317.3 2547

The White-Noise Method of Measuring Crosstalk and Noise Interference in Multichannel Telephone Link Systems—Golding. (See 2497.)

621.396.65 2548

Surveying for Microwave Relay Systems—L. E. Strazza and R. C. S. Joyce. (*Electronic Eng.*, vol. 30, pp. 262–267; May, 1958.) Surveys in well-mapped regions may involve only site and path inspections, but path tests are necessary if accuracy of path profiles plotted from maps is doubtful. Short-duration tests are used to confirm a calculated mean path loss and hence to confirm tower heights, antenna gains, and other system parameters. Long-term tests give statistical information on fading where the path profile is unfavorable. Typical test methods are described.

621.396.65 2549

A Radio Link System with Frequency Modulation for 120 Telephony Channels in the Frequency Range 1700–2300 Mc/s (FM 120/2000)—H. Holzwarth, G. Bosse, C. Colani, and E. Seibt. (*Nachrtech. Z.*, vol. 10, pp. 485–493; October, 1957.)

621.396.65:621.385.029.63/.64 2550

All-Travelling-Wave-Tube Systems—S. Fedida. (*Electronic Eng.*, vol. 30, pp. 283–290; May, 1958.) The intrinsic features of microwave repeaters using traveling-wave tubes throughout are discussed and their advantages are described. Possible sources of distortion are analyzed and methods of reducing their effect to acceptable values are indicated.

621.396.65:621.385.029.64 2551

S.H.F. Radio Links using Travelling-Wave Output Amplifiers—G. Dawson and T. K. M. Korytko. (*Electronic Eng.*, vol. 30, pp. 276–282; May, 1958.) The problems that have arisen in the planning and installation of wide-band links in many different countries are discussed. A description is given of the techniques which have been evolved in the design of the equipment and the associated supervisory and switching gear.

621.396.65:621.385.3.029.63 2552

Broad-band Microwave Systems employing U.H.F. Triodes—G. W. S. Griffith and B. Wilson. (*Electronic Eng.*, vol. 30, pp. 297–302; May, 1958.) The advantages of economy and convenience in arranging for the modulation, demodulation, and as much amplification as possible to be carried out at an intermediate frequency are discussed. In the 1700–2300-mc band, triodes are the most satisfactory means of providing amplification. Systems employing such principles are described.

621.396.65:621.396.41 2553

Microwave Radio Toll Systems—E. W. Anderson. (*Electronic Eng.*, vol. 30, pp. 267–271; May, 1958.) The function of the radio link in telephone networks is outlined and some of the problems requiring solution in the design of a short-haul or toll system carrying one supergroup are discussed. A typical system is described. The basic defect of nonlinearity in a FM system is avoided by using over-all feedback with a resulting over-all simplification of the repeater station.

621.396.65:621.397.7 2554

Portable U.H.F.-S.H.F. Links in the B.B.C. Television Service—T. H. Bridgewater. (*Electronic Eng.*, vol. 30, pp. 291–296; May, 1958.) The various types of system in use for television outside-broadcast purposes are described together with their auxiliary and test equipment.

621.396.65.029.64 2555

Microwave Link Development in the Radio Laboratories of the Post Office Engineering Department—C. F. Floyd and R. W. White. (*Electronic Eng.*, vol. 30, pp. 253–261; May, 1958.) The contribution made to wide-band microwave system development is surveyed. Work includes the design and installation of complete point-to-point 4-kmc television and multichannel telephony systems and associated test equipment. A description is given of a single-hop FM telephony link carrying 240 channels on an over-sea path of 55 miles, and a two-hop link for television transmission. Recent work on system equipment and measuring techniques is discussed and trends of development are considered.

SUBSIDIARY APPARATUS

621.314.214 2556

Variable-Output Mains Transformer—H. E. Styles. (*Wireless World*, vol. 64, pp. 262–263; June, 1958.) A design using eight windings giving voltages $2^0, 2^1 \ldots 2^7$ volts produces any integral output voltage between 0 and 255 volts by simple switching. Auto-transformer operation above 255 volts extends the range to 511 volts.

621.314.58:621.314.7 2557

Voltage Conversion with Transistor Switches—P. L. Schmidt. (*Bell Lab. Rec.*, vol. 36, pp. 60–64; February, 1958.) The conversion of a dc voltage to ac at high audio frequencies at powers of 10–100 watts is achieved using a circuit containing transistors and modern magnetic-core components.

621.314.63:546.28 2558

Failure-Rate Studies on Silicon Rectifiers—N. F. Bechtold and C. L. Hanks. (*Commun. and Electronics*, no. 35, pp. 49–56; March, 1958.) A study of the failure rate of rectifiers rated at 100–400 peak inverse volts under various conditions. Average failure rates for the 400-volt type are approximately three times those for the 100-volt type under identical conditions.

621.316.72:621.314.7 2559

Transistor filters Ripple—F. Oakes and E. W. Lawson. (*Electronics*, vol. 31, p. 95; April 11, 1958.) In a low-voltage dc power supply a capacitance of 3500 μf is effectively multiplied by 60 by the addition of a junction transistor operating as an impedance transformer.

621.316.722.1.076.25 2560

Magnetic Voltage Stabilizers—W. Taeger. (*Elektronik*, vol. 6, pp. 265–269; September, 1957.) The use of saturation effects in a number of basic designs is described; brief details of a tube-controlled automatic stabilizer circuit are given.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5:535.623:778.5 2561

The Optics of the Lenticular Colour-Film Process—R. Kingslake. (*J. Soc. Mot. Pict. Telev. Engrs*, vol. 67, pp. 8–13; January, 1958.) This type of film, which has a possible use in color television, is described and the capabilities and limitations are given. Designs of cameras, projectors, printers, and viewers are outlined.

621.397.5:778.5 2562

Monochrome Television Film Standards—K. B. Benson and J. R. Whittaker. (*J. Soc. Mot. Pict. Telev. Engrs.*, vol. 67, pp. 1–5; January, 1958.) Each stage in the production, processing, and reproduction of the film is examined. Standards for optimum results with the combined film and television system are developed.

621.397.6:621.374.4:621.318.4 2563

Magnetic-Core Dividers for ITV Sync Generators—Rose. (See 2335.)

621.397.611.2 2564

Beam Temperature, Discharge Lag and Target Biasing in some Television Pick-Up Tubes—B. Meltzer and P. L. Holmes. (*Brit. J. Appl. Phys.*, vol. 9, pp. 139–143; April, 1958.) The relation between discharge lag and the acceptance of the electron beam by the target, is analyzed and related to the calculated effective beam temperature. Results are given of the direct measurement of lag and its reduction by target biasing, and anomalous beam temperatures are discussed with regard to electron-optical measurements.

621.397.62:535.623:535.371.07.002.2 2565

Photodeposition of Luminescent Screens—Sadowsky and Payne. (See 2430.)

621.397.62:621.396.662.078 2566

Sound Signal tunes TV Automatically—C. W. Baugh, Jr., and L. J. Sienkiewicz. (*Electronics*, vol. 31, pp. 54–58; April 25, 1958.) The amplitude of the 4.5-mc intercarrier sound signal is used to control the local-oscillator frequency. As the picture level is held constant by AGC, this provides automatic fine tuning of the receiver.

621.397.7 2567

The Tasks and Structure of the Swiss Television Network—W. Gerber. (*Tech. Mitt.*

PTT, vol. 35, pp. 441–455; November 1, 1957.) (In German and French.) After tracing the development of the Swiss television network on the basis of the 625-line system details are given of its present extent and its function as part of the Eurovision network. Future planning with regard to system expansion, progress policy, and types of links to be used is discussed.

TRANSMISSION

621.396.61:621.376.3 2568

Design and Construction of a F.M. Transmitter—D. F. Bowers. (*Brit. Commun. Electronics*, vol. 5, pp. 110–114; February, 1958.) The design and performance figures of a 3-6 kw transmitter for band II are given. Parallel operation is also considered.

TUBES AND THERMIONICS

621.314.63:621.318.57 2569

Solid-State Thyratron switches Kilowatts—Frenzel and Gutzwiller. (See 2315.)

621.314.63:621.373.51:621.372.413 2570

A Proposed High-Frequency Negative-Resistance Diode—W. T. Read, Jr. (*Bell Sys. Tech. J.*, vol. 37, pp. 401–446; March, 1958.) A comprehensive description and analysis is given of a proposed semiconductor diode designed to operate as an oscillator when mounted in a suitable microwave cavity. The frequency would be in the range 1–50 kmc, the Q as low as 10 (negative), and the efficiency as high as 30 per cent. Reverse bias establishes a depletion layer of fixed width in a high-resistance region, bounded by very low-resistance end regions. The electric field has a maximum at one end of the space-charge region where hole-electron pairs are generated by avalanche; the holes (or electrons) produce diode current which is delayed about half a cycle relative to the alternating voltage, thus delivering power to the ac signal. When the diode is mounted in an inductive microwave cavity tuned to the diode capacitance, an oscillation will build up. It appears possible to exceed 20 watts in continuous operation at 5 kmc.

621.314.63+537.525.92]:681.142 2571

New Applications of Impedance Networks as Analogue Computers for Electronic Space-Charge and for Semiconductor Diffusion Problems—Čremošnik, Frei, and Strutt. (See 2308.)

621.314.632:621.372.632 2572

An Analysis of the Diode Mixer Consisting of Non-linear Capacitance and Conductance and Ohmic Spreading Resistance—A. C. Macpherson. IRE Trans. on Microwave Theory and Techniques, vol. MTT-5, pp. 43–51; January, 1957. Abstract, Proc. IRE, vol. 45, p. 576; April, 1957. See also 4036 of 1957 (Messenger and McCoy).

621.314.632:621.372.632:621.396.822 2573

Mixer Crystal Noise—N. Houlding. (Proc. IRE, vol. 46, pp. 917–918; May, 1958.) The effect of mismatches on the noise temperature ratio is considered and it is suggested that the assumption of thermal equilibrium [4036 of 1957 (Messenger and McCoy)] is unsound.

621.314.7 2574

Transient Response of Drift Transistors—R. C. Johnston. (Proc. IRE, vol. 46, pp. 830–838; May, 1958.) The short-circuit transient response of a drift transistor to a step input current is found by solving the one-dimensional partial differential equation for minority carriers in the base, using a Laplace transform technique. The improvement in rise time due to the built-in field is less in the common-emitter than in the common-base connection. The built-in field lengthens the storage time, but reduces α.

621.314.7:621.317.3 2575

An Investigation of the Current Gain of Transistors at Frequencies up to 105 Mc/s—Hyde and Smith. (See 2494.)

621.314.7:621.318.57 2576

Semiconductor Switching Devices—(*Electronic and Radio Engr.*, vol. 35, pp. 235–236; June, 1958.) A note on the characteristics of three new types of transistor. Information is condensed from articles in IRE Trans. on Electronic Devices, vol. ED-5; January, 1958.

621.314.7:621.396.822 2577

Transistor Noise: its Origin, Measurement and Behaviour—B. L. H. Wilson. (*J. Brit. IRE*, vol. 18, pp. 207–225; April, 1958.) "The sources of noise in semiconductors and the mathematical techniques needed in their discussion are indicated in order to survey the theory of noise in transistor amplifiers and to consider methods of measurement. The variation of transistor noise with operating point and frequency is discussed and a comparison is made of noise levels in audio amplifiers using transistors and tubes respectively."

621.314.7.001.4(083.74) 2578

I.R.E. Standards on Solid-State Devices: Methods of Testing Point-Contact Transistors for Large-Signal Applications, 1958—(Proc. IRE, vol. 46, pp. 878–888; May, 1958.) Standard 58 IRE 28.S1.

621.314.7.002.2:546.28 2579

Manufacture of Silicon Transistors—J. T. Kendall. (*Electronic and Radio Engr.*, vol. 35, pp. 202–207; June, 1958.) Current techniques for the production of six types of transistor are described, with a discussion of impurity distributions. Types manufactured in the U.K. and their main characteristics are listed.

621.314.7.004.2 2580

Naval Material Laboratory Transistor Reliability Study—R. E. Martin. (IRE Trans. on Reliability and Quality Control, no. PGRQC-10, pp. 49–56; June, 1957.) The effects of collector voltage, of collector power dissipation, and of ambient temperature on the reliability of low power *p-n-p* alloy-junction transistors are to be investigated in a special laboratory. 3000 samples are to be tested for 10,000 hours or longer.

621.314.7.004.2 2581

Success Story—Transistor Reliability—1956—C. H. Zierdt, Jr. (IRE Trans. on Reliability and Quality Control, no. PGRQC-10, pp. 57–68; June, 1957.) The electrical characteristics of a wide range of samples of Ge and Si junction transistors were examined under various temperature conditions and for various periods of time. Preliminary tests of the effects of nuclear radiation are also reported.

621.314.7.004.2:546.289 2582

Factors in the Reliability of Germanium Power Transistors—A. B. Jacobsen. (IRE Trans. on Reliability and Quality Control, no. PGRQC-10, pp. 43–48; June, 1957.) The reliability of a *p-n-p* alloy-junction transistor used for car receivers is discussed.

621.385.004.15 2583

A Basic Study of the Effects of Operating and Environmental Factors on Electron-Tube Reliability—W. S. Bowie. (IRE Trans. on Reliability and Quality Control, no. PGRQC-6, pp. 46–56; February, 1956. Abstract, Proc. IRE, vol. 44, p. 277; February, 1956.)

621.385.004.15 2584

Electron-Tube Life and Reliability—Built-In Tube Reliability—M. A. Acheson. (IRE Trans. on Reliability and Quality Control, no. PGRQC-7, pp. 33–43; April, 1956. Abstract, Proc. IRE, vol. 44, p. 957; July, 1956.

621.385.004.2 2585

Environmental Effects on Vacuum-Tube Life—H. C. Pleak and A. V. Baldwin. (IRE Trans. on Reliability and Quality Control, no. PGRQC-9, pp. 93–101; January, 1957. Abstract, Proc. IRE, vol. 45, p. 577; April, 1957.) See 2956 of 1957.

621.385.004.6 2586

Prediction of Tube Failure Rate Variations—M. P. Feyerherm. (IRE Trans. on Reliability and Quality Control, no. PGRQC-9, pp. 65–71; January, 1957. Abstract, Proc. IRE, vol. 45, p. 577; April, 1957.)

621.385.029.6 2587

Industrial Magnetrons—W. Schmidt. (*Elektron Rundschau*, vol. 11, pp. 306–309; October, 1957.) The differences in the requirements to be met in radar and industrial applications of magnetrons are summarized. Brief details are given of some German industrial types for operation at 2400 mc.

621.385.029.6 2588

Very-Low-Noise Travelling-Wave Amplifier—E. W. Kinaman and M. Magid. (Proc. IRE, vol. 46, pp. 861–867; May, 1958.) A general explanation of beam noise is given with a description of noise-reduction systems lowering noise figures from 9 to 6 db.

621.385.029.6 2589

Backward-Wave Oscillators—A. G. Stainsby. (*Electronic Eng.*, vol. 30, pp. 329–334; May, 1958.) These oscillators can be tuned electronically with a frequency range greater than an octave. There are two distinct types of oscillator, the O type which is mainly suited to low power operation as a local oscillator or test source, and the M type which is capable of delivering high powers with good efficiency and is thus suitable for use as a transmitter.

621.385.029.6 2590

Understanding the Backward-Wave Oscillator—D. A. Dunn. (*Electronic Ind.*, vol. 17, pp. 72–76; January, 1958.) An explanation of the physical processes which take place in backward-wave oscillators.

621.385.029.63/.64 2591

Travelling-Wave Tubes in Communications.—R. B. Coulson. (*Electronic Eng.*, vol. 30, pp. 302–304; May, 1958.) Their application in microwave repeaters and the use of electromagnets in preference to permanent magnets for beam focusing is discussed.

621.385.029.63/.64 2592

Travelling-Wave-Tube Amplifiers—D. H. O. Allen. (*Electronic Eng.*, vol. 30, pp. 305–309; May, 1958.) The major advances made towards a reliable and useful tube are discussed with particular reference to noise characteristics and focusing methods. Applications to microwave links and the distortions that may arise under various operating conditions are also discussed.

621.385.029.63/.64 2593

S-Band Travelling-Wave Tube with Noise Figure below 4 dB—M. Caulton and G. E. St. John. (Proc. IRE, vol. 46, pp. 911–912; May, 1958.) Modifications to the electrode configuration and voltage profile of a conventional low noise traveling-wave tube produced a hollow beam and a low velocity drift region near the cathode. Noise figures down to 3.5 db were obtained.

621.385.029.63/.64 2594

Reflex Klystrons—A. H. Atherton. (*Electronic Eng.*, vol. 30, pp. 315–320; May, 1958.) A general description of the construction and operation of reflex klystrons is given, with typical examples.

621.385.029.63/.64 2595

Multicavity Klystrons—V. J. Norris. (*Electronic Eng.*, vol. 30, pp. 321–323; May, 1958.) "A review is given of the factors determining the gain, efficiency, and bandwidth of multicavity klystrons, together with results which have been achieved in practice."

621.385.029.63/.64:621.372.414 2596

Coaxial-Line Velocity-Modulated Oscillator Valves—D. E. Lambert. (*Electronic Eng.*, vol. 30, pp. 324–328; May, 1958.) The principle of operation of these tubes is discussed, and also their advantages and limitations. A list of tubes in production is given.

621.385.029.64 2597

Traveling-Wave Tubes for 4000 Mc/s—P. F. C. Burke. (*Electronic Eng.*, vol. 30, pp. 310–314; May, 1958.) Traveling-wave tubes may be used in microwave radio links as output amplifiers, low-noise receivers, and intermediate-level amplifiers. Examples are given of applications at frequencies near 4 km.

621.385.032.213.13 2598

High-Emission Hot Cathodes of New Type—T. Hashimoto, M. Uchida, and A. Yokoyama. (*Rep. Elect. Commun. Lab., Japan*, vol. 5, pp. 4–8; December, 1957.) Research has been carried out on cathodes impregnated with various barium compounds for use in microwave tubes. Work has also been done on sintered cathodes. Details of life tests are given. See also 1927 of June (Hashimoto).

621.385.032.213.13 2599

A Sintered Nickel Matrix Cathode—R. W. Fane. (*Brit. J. Appl. Phys.*, vol. 9, pp. 149–153; April, 1958.) Cathodes containing alkaline earth carbonates and boron have given 8000 hours life at current densities in excess of 0.5 a/cm^2. Processing schedules and operating temperatures are similar to those for normal oxide-coated types. Possible mechanisms of operation are discussed.

621.385.032.269.1 2600

A New Type of Low-Noise Electron Gun for Microwave Tubes—M. R. Currie. (Proc. IRE, vol. 46, p. 911; May, 1958.) Noise figures of 3.5 db are obtained with the gun system whose basic features are described.

621.385.1+621.387 2601

Thermionic and Cold-Cathode Valves—W. H. Aldous. (*Proc. IEE*, pt B, vol. 105, pp. 273–281; May, 1958.) A full survey of tube development since 1933 is given, with particular emphasis on the decrease in size of all types of tubes.

621.385.3 2602

On the Amplification Factor of a Triode Valve: Part 2—E. B. Moullin. (*Proc. IEE*, pt. C, vol. 105, pp. 196–202; March, 1958.) A description of measurements designed to test the degree to which the amplification factor is independent of the anode current (see 2649 of 1957).

621.385.3/.4].029.63/.64 2603

Triodes and Tetrodes for U.H.F.-S.H.F. Operation—C. A. Tremlett and A. D. Williams. (*Electronic Eng.*, vol. 30, pp. 335–340; May, 1958.) A review of the advances made over the last ten years in the development of space-charge-controlled tubes for operation above 300 mc. Tube geometry and performance data for various types are listed.

621.385.832:621.317.755 2604

Broad-Band Oscilloscope Tube—Brangaccio, Dietrich, and Sullivan. (See 2510.)

MISCELLANEOUS

061:621.3(436)(091) 2605

75 Years of the Elektrotechnischer Verein Österreichs—(*Electrotech. u. Maschinenb.*, vol. 75, pp. 177–340; May 1, 1958.) The history of the Association and its journal are outlined and the contributions of Austrian scientists and engineers in the field of electrical engineering are summarized in a number of papers which include the following:

1) **The Development of Electrical Communications in Austria**—H. Schmid. (pp. 300–320.)

2) **The Contribution of Austria in the Development of High-Frequency Engineering**—C. Caspar. (pp. 320–326.)

3) **Austria's Contribution in the Development of Electroacoustics**—F. Lachner. (pp. 330–332.)

621.3.029.6(091) 2606

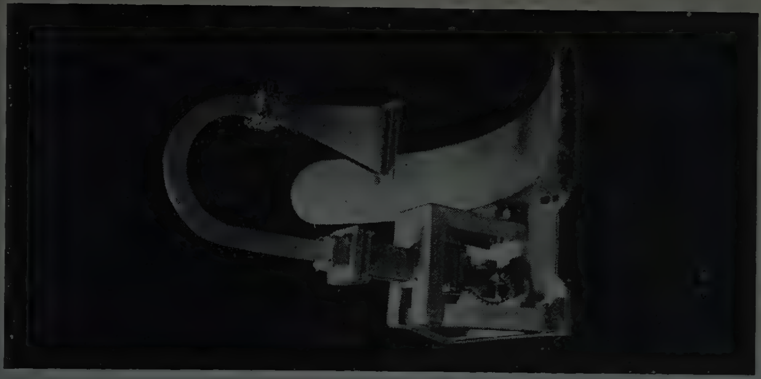
Microwaves—E. L. Ginzton. (*Science*, vol. 127, pp. 841–851; April 18, 1958.) The historical development of microwave research is reviewed and current applications and techniques are outlined.

621.3.049 2607

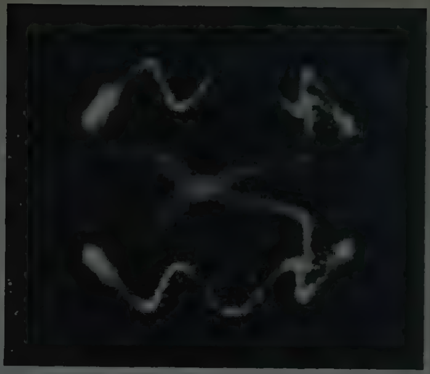
Optimum Tolerance Assignment to Yield Minimum Manufacturing Cost—D. H. Evans. (*Bell Sys. Tech. J.*, vol. 37, pp. 461–484; March, 1958.) The basic item considered is a unit with a single nominal design response, having several components with given nominal design values such that the unit response is as required. Tolerance assignment is considered in relation to cost and salvage value of a unit, and statistical results are presented.

621.3.049:621-52 2608

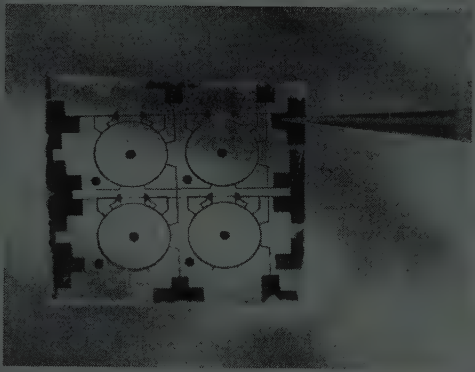
Automatic Methods in Radio Component Manufacture—D. Stevenson and R. B. Shepherd. (*J. Brit. IRE*, vol. 18, pp. 227–231; April, 1958.) Two special systems are described: a) an electronic counter technique applied to the accurate control of a high-speed coil winding machine; b) a power press producing ferrous piece-parts protected from jamming by detecting each ejected part magnetically.



Horn fed parabolic reflector antenna for airborne applications.



Charged aluminum particle suspended and controlled in a vacuum chamber by an oscillating electric field.



The Persistor gives promise of cryogenic computer memories with a capacity of 1,000,000 bits per cubic foot and access times of 1/30 microsecond.

Ground based data handling equipment for processing analog and digital reconnaissance information.

Data conversion system for digitizing and processing telemetered missile test data.

Electron micrograph of impact produced on aluminum coated glass by a 1 micron diameter particle traveling at 7,000 feet per second.

Pictorial **PROGRESS REPORT**

The photographs above illustrate some of the recent research, development, and manufacturing activities at Ramo-Wooldridge. Work is in progress on a wide variety of projects, and positions are available for scientists and engineers in the following fields:

- Digital Computers and Control Systems
- Communications and Navigation Systems
- Guided Missile Research and Development
- Infrared Systems
- Electronic Countermeasures
- Electronic Instrumentation and Test Equipment
- Basic Electronic and Aeronautical Research

The Ramo-Wooldridge Corporation

LOS ANGELES 45, CALIFORNIA

TRANS-SONICS

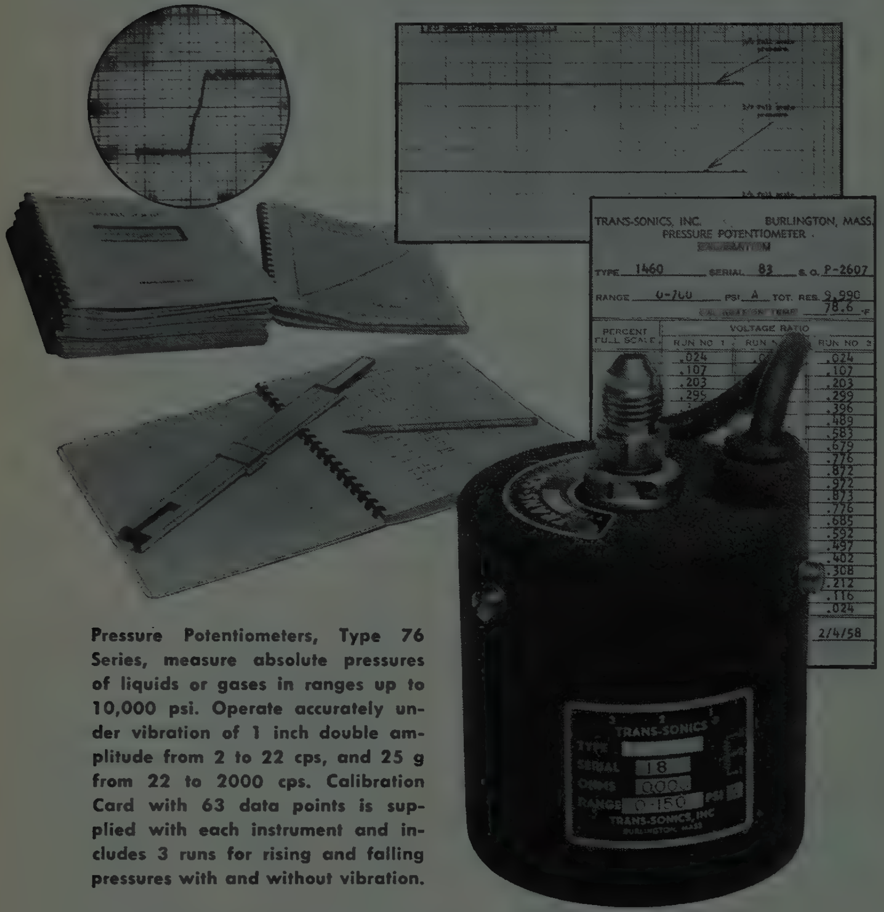
REG. T.M.

PRESSURE POTENTIOMETERS

Beyond the Specifications...

Visit us . . . IRE NATIONAL SYMPOSIUM ON TELEMETRY, Sept. 22-24 Miami Beach, Fla., Booths 1 & 2.

the Total Engineering Story



Pressure Potentiometers, Type 76 Series, measure absolute pressures of liquids or gases in ranges up to 10,000 psi. Operate accurately under vibration of 1 inch double amplitude from 2 to 22 cps, and 25 g from 22 to 2000 cps. Calibration Card with 63 data points is supplied with each instrument and includes 3 runs for rising and falling pressures with and without vibration.

Specifications tell part of the story. At Trans-Sonics, Inc., they are only the beginning. For each basic design, three volumes of evaluation tests are available containing thousands of individual data points. Essential information on performance under temperature, vibration, shock and humidity is investigated, sifted out and recorded for easy reference.

This extensive data enables the user to quickly evaluate performance under new or unexpected environmental conditions. As a result, greater design freedom is possible and valuable engineering time is saved. Write to Trans-Sonics, Inc., Dept. 15, Burlington, Massachusetts, for Pressure Potentiometer Bulletin; or if you prefer, describe your operating environment and quantitative information will be provided.

TRANS-SONICS

Precision Transducers

MAKE IT 3 or 5 SPARKLING and INSTRUCTIVE DAYS at the 1958

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September 22-24, 1958
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SESSIONS

Monday, Sept. 22

Session I (five papers)
DIGITAL TECHNIQUES

Session II (six papers)
TRANSISTOR TELEMETRY COMPONENTS

Session III (six papers)
TELEMETRY IN SPACE

Session IV (six papers)
NEW COMPONENTS IN TELEMETRY

Tuesday, Sept. 23

Session V (six papers)
DATA RECORDING AND PROCESSING

Session VI (five papers)
NEW RADIO FREQUENCY TECHNIQUES AND PROBLEMS

Session VII (five papers)
DYNAMIC TESTING IN THE SPACE AGE

Session VIII (five papers)
MODULATION—METHODS IN TELEMETRY

Wednesday, Sept. 24

Session IX (five papers)
THE INSTRUMENTATION OF OUTER SPACE

Session X (six papers)
RECENT TECHNICAL ADVANCES IN COMMUTATORS

Session XI (five papers)
NEW TELEMETRY SYSTEMS

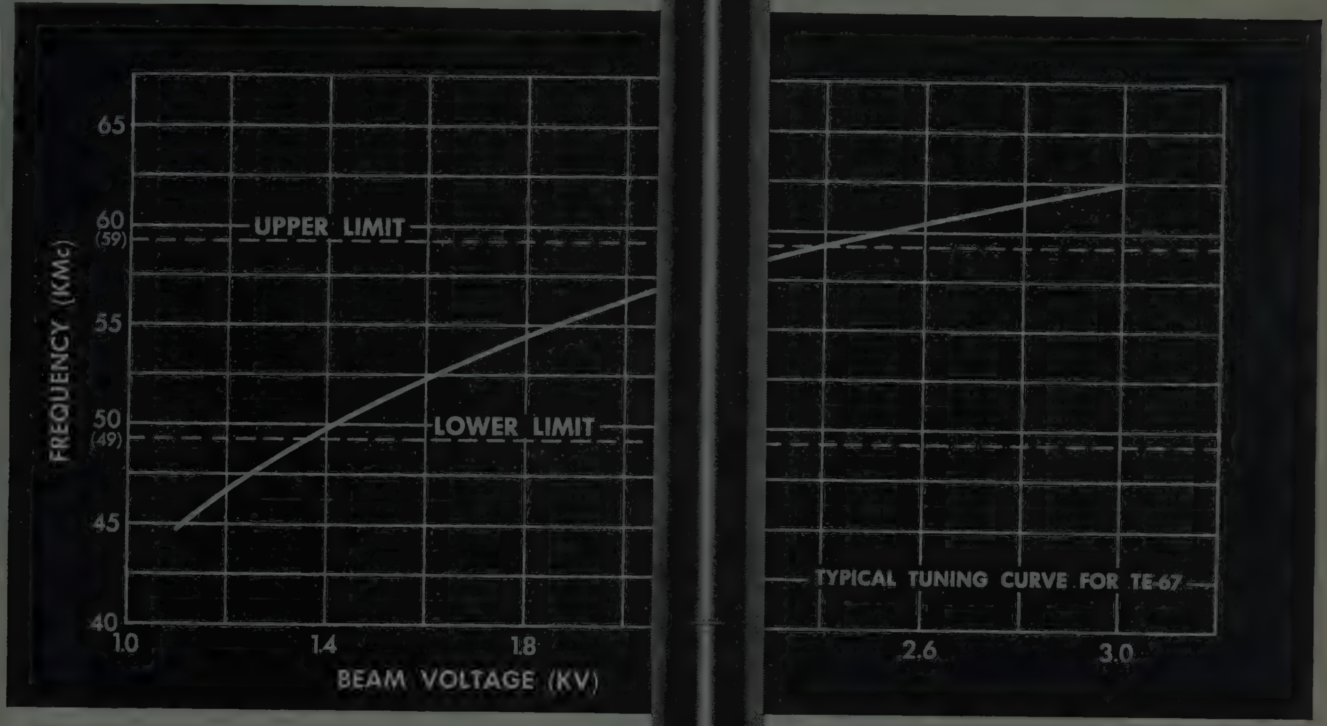
Session XII (five papers)
TIME DIVISION MULTIPLEXING SYSTEMS

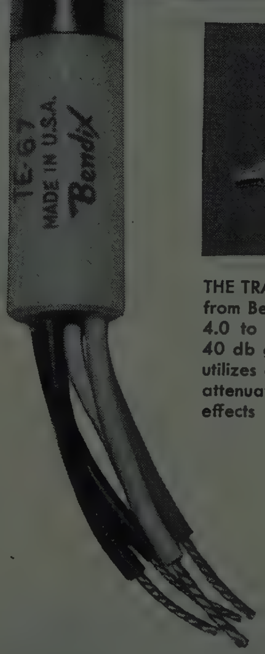
(Continued on page 101A)

New Bendix®

BACKWARD-WAVE OSCILLATOR TUBE

for extremely high frequencies





An exclusive Bendix Red Bank product, the Type TE-67 Backward-Wave Oscillator Tube generates microwave energy at extremely high frequencies never before available.

This new tube provides a wide range of usable frequencies for applications in: advanced types of multichannel telephone and television systems, high definition short-range radar, highly directive communications, microwave spectroscopy and other fields where low power, voltage-tuned millimeter wavelength radio frequency energy is required. As the backward-wave tube is voltage tuned, frequency is automatically changed by varying the voltage input. No mechanical tuning adjustment is required.

For more detailed information on the tubes described here, write to: RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

ELECTRICAL DATA

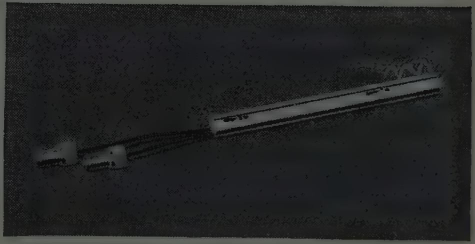
Frequency Range	49kmc—59kmc
Anode Voltage	1000—3000 volts
Power Output	5mw average
Beam Current	5ma
Magnetic Field	1300 gauss (minimum)
Heater Voltage	6.3±10%

MECHANICAL DATA

Output Flange	Special adapter to RG-98/U
Maximum Diameter	0.625″
Length	8″
Mounting Position	Any
Weight	5 oz.*

*Without magnet (tube only). Magnets are available.

Additional tubes are under development to extend the frequency range to 75 kmc.



THE TRAVELING-WAVE AMPLIFIER TUBE, also available from Bendix Red Bank, is designed for operation in the 4.0 to 8.0 kmc frequency range with approximately 40 db gain and 200 milliwatts output power. The tube utilizes a helical slow-wave structure with coupled helix attenuator section. The mechanical design minimizes the effects of vibration upon the tube operation.

West Coast Sales & Service: 117 E. Providencia Ave., Burbank, Calif. • Export Sales & Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y. Canadian Distributor: Computing Devices of Canada, Ltd., P.O. Box 508, Ottawa 4, Ontario

Red Bank Division

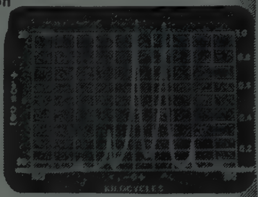
Bendix
AVIATION CORPORATION

Operator adjusts Panalyzor gain control to spectrum analysis readings in two tone linearity test of Technical Materiel Corporation SSB transmitter, Model No. GPT-750D. Model SB-12a Panalyzor permits precise readings of in-band intermodulation products down to 60 db. Courtesy: Technical Materiel Corporation.

NOW

60 db range ...fewer control settings in analyzing SSB (Single Side Band) TRANSMITTER LINEARITY

Intermodulation distortion components are seen either side of carrier (center) and upper 1Kc side band in two tone test of SSB transmitter



PANORAMIC'S new SB-12a PANALYZOR

- **Measures in-band (odd order) intermodulation products precisely down to —60 db**
- **New 20 db attenuator multiplies main tones permitting smaller sideband levels to be read accurately**
- **Continuously variable sweep, resolution, and scan rate PLUS . . .**
- **New fixed sweep widths of 150, 500, 2000 and 10,000 cps with . . .**
- **Resolution and gain automatically optimally tracked**
- **10 cps side band resolution capabilities**
- **Improved I.F. skirt selectivity aids in hum analysis**
- **5" High Persistence CRT with camera mount**
- **New Vertical and Horizontal Outputs for auxiliary graphic recorder (Model RC-3) or large screen CRT**

Here's the instrument you've been waiting for. Specifically designed for SSB (single side band) investigations, the SB-12a's highly convenient pre-set narrow band scans, range-extending attenuator, speed the standard two-tone test, hum sideband determinations and other spectrum measurements. Like other Panoramic Panalyzors, the SB-12a measures RF signals up to 1000 mc by heterodyning in the input stage converter and using an external VFO.

An input center frequency of 500 kc . . . maximum deviation of ± 50 kc . . . a high order of sweep stability (AFC on scans up to 2 kc) . . . 10 cps resolution capability . . . and extended dynamic range, make the new SB-12a uniquely suitable for rapid visual analysis of

• dynamic transmission band occupancy • nonlinearities such as intermodulation products and sideband splatter • residual carrier and suppressed sideband levels • hum and other low frequency modulations • out of band radiations such as RF harmonics, parasitics, etc.

Write, wire, phone TODAY for technical bulletin on the new SB-12a.

the pioneer is the leader

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Send for Panoramic's 1958 CATALOG DIGEST and ask to be put on our regular mailing list for The PANORAMIC ANALYZER featuring application data.

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Cables: Panoramic, Mount Vernon, New York State

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announcing

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Seven prime advantages are (1) a complete single or multiple brush assembly ready to use, (2) no welding or soldering, (3) reduction of adjustment during assembly into unit, (4) insured uniformity of desired gram pressure, (5) reduced inspection costs, (6) time tested Ney alloys for reliability, (7) will withstand extremes in operating environments.

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NEY

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P.O. Box 990, Dept. I, Hartford 1, Conn.

onal Symposium on Telemetering

(Continued from page 98A)

SPECIAL EVENTS

ay
up Luncheon—12:30 p.m.
ay
ktail Party—6:00-7:30 p.m.
quet—8:00 p.m.
esday
up Luncheon—12:30 p.m.
lay
sified Meeting under the auspices of Air
ce Missile Test Center (Clearance must be
ained in advance)

r of Cape Canaveral

ssions, exhibits and events under one roof—
beautiful Americana Hotel, Miami Beach,
a.

EXHIBITORS

pany	Booth No.
x Products Co.	320-321
ex Corp. *See ad on page 101A*	206-207
ed Science Corp.	412
x Corp.	208-209
x Aviation Corp. *See ad on page 99A*	13-14
uter Control Co., Inc.	204
olidated Electrodynamics	406
Corp.	401
Control Systems, Inc.	101-102
it Diesel Eng. Div., General Motors rp.	28-29
mic Gear Co., Inc.	201
o-Mechanical Research	4-5
, Inc.	18-19
e, Fedrick & Miller	311
ral Devices, Inc.	310
ral Electronic Labs., Inc.	106
n Industries, Inc.	214
more Electronics Co.	312
day-Hathaway	105
es & Assoc., E. J.	308-309
er Electronics	205
n Eastern, Inc.	301
ment Development Labs.	107
Industries of Calif.	419
& Assoc., Arthur H.	20-21
etic Research Corp.	213
eapolis-Honeywell Reg. Co., Davies .	409
estern Instruments, Inc.	211-212
hy & Cota	410-411
lex Electronics Corp.	303
-Clarke Co.	6-7
Co., J. M. *See ad on page 100A*	302
amic Radio Products *See ad on page 100A*	216-217
tion, Inc.	103-104
rome Mfg. Corp.	3
Dynamics, Inc.	22-23
Sonics, Inc. *See ad on page 98A*	1-2
rsal Match Corp., Armament Div.	418
ham Electronic Corp.	408

Newest
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AMPEX PRECISION REELS in 10½- or 14-inch diameters assure perfect guidance and winding even on thin 1-mil Mylar* tapes.

FOUR INTERCHANGEABLE AMPLIFIERS are available for each track. NRZ digital amplifiers have been added. Others are Direct, FM Carrier, and PDM (Pulse Duration Modulation).

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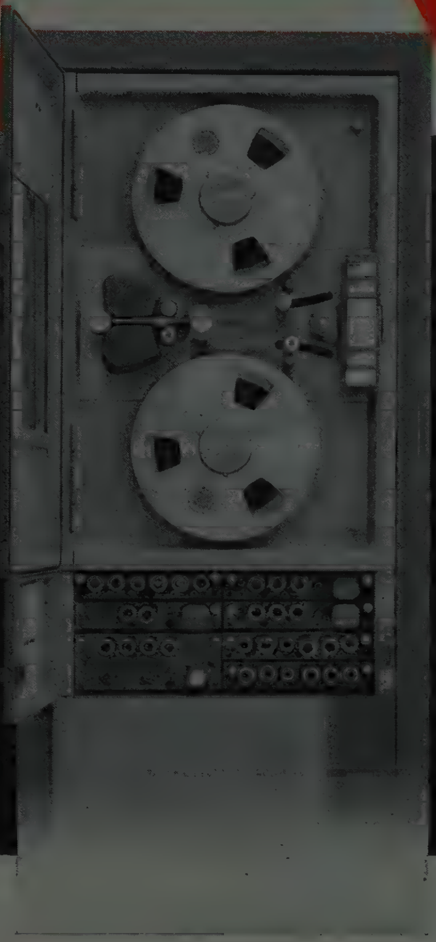
ACCESSORIES include footage counters, remote control panels, rack dollies, head switches, new meter panels and additional plug-in options.

*DUPONT TRADEMARK



32-TO-1 TAPE SPEED RATIO includes six standard speeds from 1⅞ to 60 in./sec., giving recording time as long as 12 hours or frequency response as high as 100,000 cycles per second.

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Versatile magnetic tape recorder for data and control

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For technical information, write Dept. G-FR-100A

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- ***Comprehensive Tube, Transistor, Crystal Diode, and Picture Tube Testing.***
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- ***Functional Testing of Voltage Regulator Tubes.***

TUBE TESTING FEATURES

- **Positive, all-inclusive tube performance testing** . . . not limited to mutual conductance alone
- **Tests tubes over a complete path of operation** . . . not at just one arbitrary point
- **Actively tests all tube elements in *PRECISION*** Electronamic tube testing circuit
- **Tests all modern tube types** . . . including sub-miniatures
- **Dual short-check sensitivity.** Special low voltage short-check circuit guards against damage to tubes under test
- **Built-in stainless steel pin-straighteners** for 7 and 9 pin tubes
- **Functionally tests voltage regulator tubes** for voltage regulation at manufacturer's specified current limits
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- **TV picture tubes tested in specially engineered circuit** — for picture producing beam current (requires optional accessory PTA picture tube cable adapter and PAA 110° socket adapter).

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- Designed in accordance with recommendations of leading semiconductor manufacturers
- I_{cbo} readings directly related to true collector current
- Wide spread I_{cbo} ranges cover all types of transistors — low, medium and high power
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MODEL 10-60: Etched, satin-brushed aluminum panel. Sturdy carrying case with tool compartment and removable cover. Dimensions: 20 x 15 x 7". Code: FRIAR ....**Net Price: $195.00**

PICTURE TUBE TESTING ACCESSORIES AVAILABLE—
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AVAILABLE SOON

MODEL 10-40 — Physically and electrically similar to Precision Model 10-60, but without transistor and crystal diode testing facilities.
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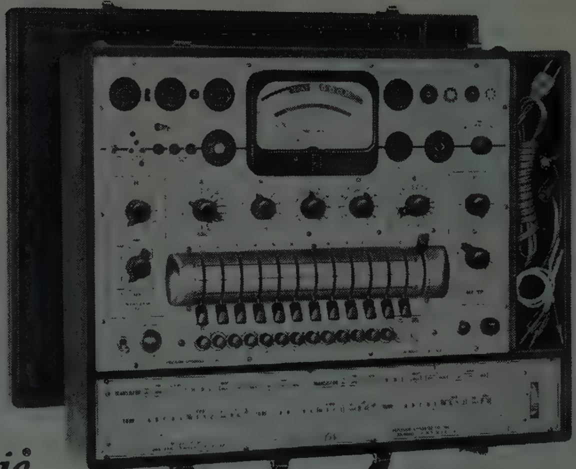

Section Meetings

(Continued from page 94A)

Fort Wayne

"Nuclear Radiation Effects on Electronic Equipment," J. Frazier, G. E. Co.; Joint Meeting with PGME; 5/1/58.

"Exploring the University with Radio," J. W. Findlay, Nat'l Radio Astronomy Observatory; 6/5/58—Joint Meeting with PGME.

Huntsville

"The Utilization of Solar Radiation for Electric Power," G. M. Branch, G. E. Co.; 6/24/58.

Ithaca

"IRE Editorial Policy," Donald G. Fink, President IRE; 6/20/58.

Kansas City

Annual Picnic; 6/21/58.

New York

"Plasma and Cyclotron Oscillations," M. Ettenberg, Columbia Univ.; Joint Meeting with PGED; 2/5/58.

"Computers in Research," H. R. J. Grosch, IBM; 3/5/58—Joint Meeting with PGEC.

"Air Traffic Control," H. S. Stokes, Airways Modernization Board; Joint Meeting with PGANE; 4/2/58.

"Humor Applied to Circuit Problems," S. H. Mason, MIT; 5/7/58.

Omaha-Lincoln

Panel Discussion, R. Ralls, Strategic Air Command; 4/8/58.

"Dial-To-Dial Mobile Telephony," R. Stewart, Motorola; 4/11/58.

"F.C.C. Monitoring Station Activities," A. A. Johnson, Grand Island F.C.C. Station; Joint Meeting with PGVC; 6/14/58.

Phoenix

"Electronic Engineering in England," H. daCosta, Motorola Res. Lab.; 6/20/58.

Portland

"Aircraft Relay Design," J. Deer, Iron Fireman Electronics Div.; 6/26/58.

Sacramento

"Engineering in Europe Today," W. J. Kerth, Technical Consultant 1960 Winter Olympics; 6/24/58.

San Diego

"Computer Applications in Industry," M. Otis, Daystrom Systems; 7/1/58.

Shreveport

"KSLA-TV Facilities," M. Barton, KSLA-TV Sta.; 6/3/58.

Toledo

Films: DEW Line Installation in the Far North; Bell Telephone System; WE Mfg. Co.; 6/12/58.

Western Massachusetts

Annual Ladies' Night: IRE Discussion, Donald G. Fink, President of IRE; "New Advances in Electronics," C. N. Hoyler, David Sarnoff Res. Center, RCA; 7/1/58.

(Continued on page 104A)

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Bulletin PC-104 B . . . Complete data on Mo-Permalloy Powder Cores.

Bulletin GC-106 C . . . General information on Magnets and other Arnold products.

Bulletin SC-107 . . . Covers the complete range of Arnold Silectron Cores.

Bulletin TC-108 A . . . Describes properties, etc. of Arnold Bobbin Cores.

Bulletin PC-109 . . . Essential data on Arnold Iron Powder Cores.

Bulletin SDC-110 . . . Information on properties, etc. of Sendust Powder Cores.

Bulletin TC-113 A . . . Technical data on Arnold Supermendur Tape Cores.

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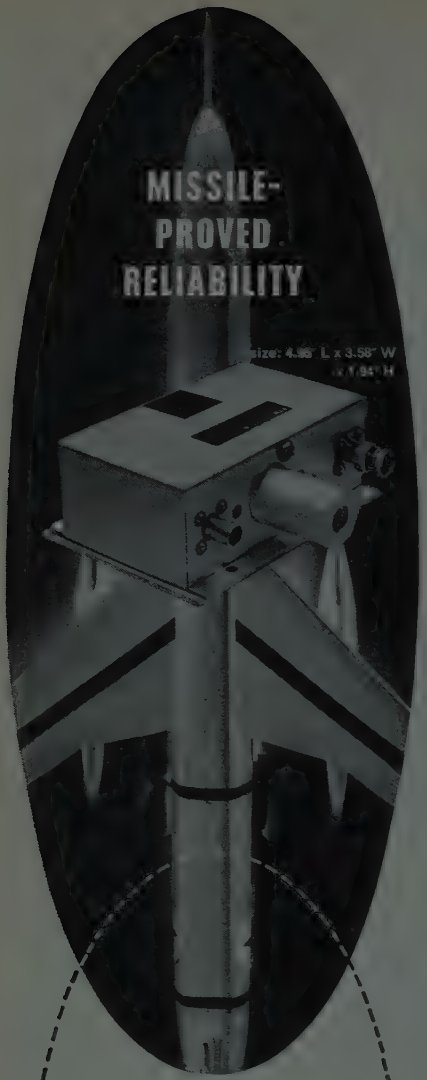

in the 235 mc
to 245 mc
telemetering band

The Model REL-09-HF is a ruggedized miniature R-F power amplifier. With a solid history of reliability in current missile systems, the unit has proved capable of withstanding the most rigorous airborne applications. The 5-inch, 1-pound amplifier delivers an 8-watt output to a 52-ohm load with a 1.4-watt input drive.

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Section Meetings

(Continued from page 102A)

SUBSECTIONS

GAINESVILLE

"Extended Theory of Thin Wire Loop Antennas," J. Herman, Diamond Ordnance Fuze Labs.; 5/21/58.

LANCASTER

"History of Lancaster Subsection on Occasion of Tenth Anniversary," P. A. Metzger, RCA; 6/19/58.

MID-HUDSON

"Upper Air Research with Rockets," M. D. O'Day, Air Force Cambridge Res. Center; 3/6/58.

"Ethics for Engineers," P. L. Alger, G. E. Co.; 3/18/58.

"Direct Distance Dialing," A. Cuerdon, N. Y. Tel. Co.; 3/19/58.

"Progress in Electroluminescence, a New Dimension in Lighting," C. F. Jensen, Westinghouse Lamp Div.; 2/19/58.

"Electronic Applications in Geophysics," S. Katz, Rensselaer Polytechnic Institute; 4/16/58.

"Mavar Amplifiers," A. G. Fox, Bell Tel. Labs.; 5/21/58.

Annual Field Trip; 6/18/58.

QUEBEC

"Energy Losses in Accelerometer," G. Tillotson, Acadia Univ.; 6/12/58.

SAN FERNANDO VALLEY

"Plane Anti-Collision System," Y. J. Lui, J. Campbell, Aerosystronics Corp.; 6/11/58.

SANTA BARBARA

"Automatic Noise Figure Measurement," H. C Poulter, Hewlett Packard Co.; "Coincident Sound System," J. N. Whitaker, Hughes Aircraft Co.; 5/13/58.

WESTCHESTER COUNTY

"Infra-Red Theory and Techniques at the Dawn of the Space Age," H. Dubner, ACF Industries; 5/21/58.

WESTERN NORTH CAROLINA

"Problems and Progress in Space Satellites," S. B. McLean, Jr., Davidson College; 3/21/58.

"Semi-Conductors," J. G. Walton, A. B. Dall, G. E. Co.; 4/11/58.

"The Charlotte Technical College, Its Administration and Technical Education Facilities," W. R. Holstead, Charlotte College; 5/16/58.

"Color Video Tape Recording," F. F. Bateman, Jefferson Standard Broadcasting Station WBTV; 6/20/58.

1959
Radio Engineering
Show and
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New York Coliseum and
Waldorf Astoria Hotel
March 23-26, 1959

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More engineers *NEED Proceedings of the IRE* than need any other radio-electronic engineering magazine. 54,257 (ABC December 31, 1957) plus 11,433 students, to be exact. This is not promised—but delivered circulation.

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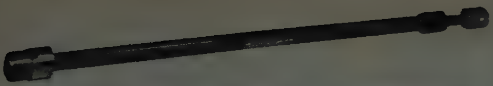


MODEL 372 SLIDING COAXIAL TERMINATIONS

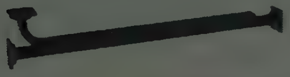
This equipment, available only from Narda, provides the most convenient means for evaluating the residual VSWR of coaxial slotted lines. VSWR of the element is 1.05 or less; covers range from 2000 to 12,400 mc.

N Connector, male or female **$110** C Connector, male or female **$116**

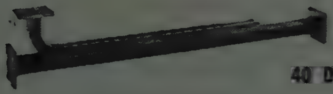
MODEL 371 FIXED COAXIAL TERMINATION

This Narda coaxial termination is the first and only to cover the entire frequency range from S to X band. Same range and element VSWR as above.

N Connector, male or female **$55** C Connector, male or female **$58**



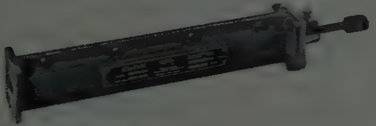
3, 6, 10 and 20 DB



40 DB HIGH POWER

HIGH DIRECTIVITY COUPLERS

The 40 db High Power Coupler is another exclusive Narda product. Similar to standard types, except that coupling irises are in the narrow wall, it may be used at full rated power of the waveguide size. Nominal coupling value is 40 db; directivity 40 db. Directivity for 3, 6, 10 and 20 db couplers is also 40 db. Standard cover flanges on primary line; low VSWR termination and standard cover flange on secondary. All bands covering frequencies from 2600 to 18,000 mc.



STANDARD REFLECTIONS

Narda offers five values of reflections for each of six different waveguide sizes . . . the most complete choice we know of! Provides calibrated reflections or VSWR's for use in standardizing reflectometers or calibrating slotted line impedance meters.

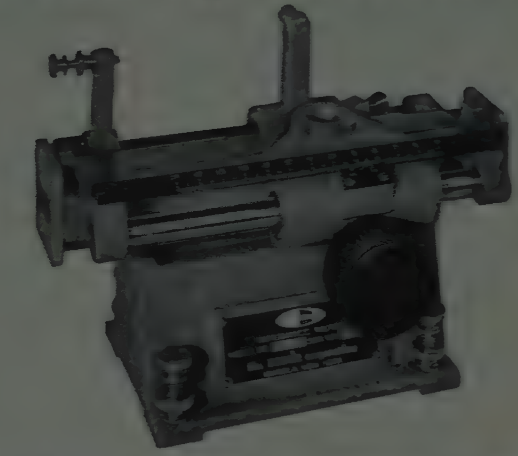
SPECIFICATIONS

Reflection Coefficient	0.00	0.05	0.10	0.15	0.20
Accuracy	0.002	0.0025	0.0035	0.0045	0.007
VSWR Equivalent	1.00	1.105	1.222	1.353	1.50

Models for 2.60 to 18.0 kmc, from $125 to $300

Microwave engineers–

Where can you use these exclusive features offered by narda?



Waveguide and Coaxial IMPEDANCE METERS

Exclusively in Narda Waveguide and Coaxial Impedance Meters, the carriage mounting and drive mechanism are integral with the precisely machined transmission line casting. This insures permanent accuracy and freedom from slope errors—no more tedious adjustment or possibility of misalignment.

Other features include angle-mounted scale and vernier for optimum visibility; readily removable supporting pedestal; and smooth carriage travel action. Waveguide models, accurate for VSWR's of 1.01, are available for complete coverage from 2600 to 18,000 mc; N or C Connector coaxial models, from 1500 to 12,400 mc.

WAVEGUIDE IMPEDANCE METERS

Frequency (kmc)	Narda Model	Residual VSWR	Price
2.6 — 3.95	224	1.01	$425
3.95— 5.85	223		350
5.3 — 8.2	222		325
7.05—10.0	221		270
8.2 —12.4	220		250
12.4 —18.0	219		270

COAXIAL IMPEDANCE METERS

Frequency (kmc)	Connectors One Male, One Female	Narda Model	Price
1.5 to 12.4	Series N	231	$360
1.5 to 12.4	Series C	232	390

Complete Coaxial and Waveguide Instrumentation for Microwaves and UHF—including:

DIRECTIONAL COUPLERS
TERMINATIONS
FREQUENCY METERS
HORNS
TUNERS
ECHO BOXES
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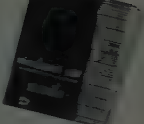


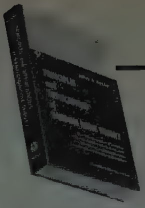
The Narda Microwave Corporation
160 Herricks Road
Mineola, N.Y.
Dept. PIRE-I

NAME________________________

COMPANY________________________

ADDRESS________________________

CITY____________ZONE____STATE____________



JUST OUT!

PRINCIPLES AND APPLICATIONS OF RANDOM NOISE THEORY

By JULIUS S. BENDAT, Ramo-Wooldridge Corporation

A thoroughly comprehensive explanation of the fundamental ideas in random noise theory, which bridges the gap between the research scientist and the practicing engineer. Contains a full treatment of Rice's representation of random noise, *plus* the only development of the important Zero Crossing problem. Gives details on errors in measuring power spectra and correlation functions, and discusses statistical detection theory, limitations, assumptions, and analytical details.

Every chapter is chock full of valuable information! Check these headings:

- **Random Processes, Engineering Systems, Correlation Functions**
- **Power Spectra and Relationships**
- **Probability Theory, Random Noise Analysis**
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- **Exponential-Cosine Autocorrelation Functions**
- **Analog Computer Techniques**
- **Statistical Errors in Autocorrelation Measurements**
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Industrial Engineering Notes*

EIA Activities

At the 27th annual convention of RETMA of Canada, in Toronto, the association changed its name to Electronic Industries Association to better describe the diversified products of its member companies. At the same time, Ronald M. Robinson, Vice-President and General Manager of the Electronic Equipment and Tube Department, Canadian General Electric Co., Ltd., Toronto, was named 1958–1959 President, succeeding W. H. Jeffery, Philco Corp. of Canada, Ltd., Toronto. . . . **The EIA-sponsored plan to reprint the "FCC Non-Government Frequency Assignment Lists" as a service to the communications industry has received enthusiastic endorsement of all branches of the industry.** Subscriptions and inquiries concerning the service have been received from such diverse sources as manufacturers, aeronautical and industrial, telephone, trucking, broadcasting, engineering, marine-forestry-petroleum, maintenance, county road commissioners, consultants, state communications divisions, and others. It is expected that the first volume will be mailed in August or early September. The various "Lists" will not be reprinted simultaneously but will be issued sporadically throughout the entire year, as the data are released by the FCC. The "Lists" will follow the same official form as those used by the FCC and other government personnel. Further information can be obtained by writing Donald H. Stover, EIA Headquarters, 1721 DeSales St., N.W., Washington 6, D.C. . . . **EIA has filed comments with the FCC in Docket 11986, a rule-making proceeding issued for the purpose of adopting a standard test signal to be transmitted by TV broadcast stations.** The comments were prepared by the Broadcast Television Systems Committee of the Association, under the Chairmanship of C. J. Hirsch, of Hazeltine Research Corp. The BTS Committee took the position that a standard signal should not be

(Continued on page 108A)

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* The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of June 30, and July 14 and 21, published by the Electronic Industries Association whose helpfulness is gratefully acknowledged.

NEW, LOW FREQUENCY RELIABILITY IN GLASS-ENCLOSED CRYSTAL

Precision components of the new RHG-DP crystals are enclosed and hermetically sealed in glass holders to assure maximum internal cleanliness and most reliable evacuation. The result is a series of sturdy, miniature, low frequency units having excellent long-term stability and higher Q.

TYPICAL VALUES FOR 2 KC UNIT*

Frequency range	1 to 15 kc
Holder	T5 1/2 glass bulb —Noval Base
Temperature range	−55 to +100°C
Frequency tolerance	±.015%
Effective resistance	75,000 ohms max.
Aging 8 hours—100°C	±.001% max.

Meets MIL specifications for vibration stability

*Reeves-Hoffman manufactures a broad line of crystals in the range from 1 to 1000 kc.

REEVES-HOFFMAN

WRITE FOR BULLETIN RHG-DP

DIVISION OF DYNAMICS CORPORATION OF AMERICA
CARLISLE, PENNSYLVANIA

THE BIG LOOK

IN GENERAL ELECTRIC'S NEW PANEL INSTRUMENTS

5
10
15
0
20
D-C
MICROAMPERES
GENERAL ELECTRIC
TYPE DO-91
CAT 8803T

DISTINCTIVE APPEARANCE

Clean-line design sparkles with functional new beauty—adds a distinctive touch to your finest switchboards and panels. Big border-to-border scale is framed in aluminum for better color blending. Design innovation creates the illusion of bigness, yet they fit into the same useable space as old style instruments.

EXCELLENT READABILITY

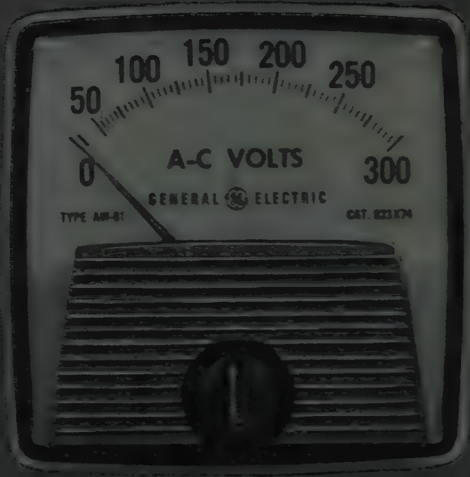
BIG LOOK styling provides up to 28% increase in scale length over types replaced. Easy-to-read numerals cannot be obscured by the slim, tapered pointer. Clear raised window allows natural light to flood scale area, keeping shadows out.

RELIABLE OPERATION

Self-shielding: Exclusive moving-magnet mechanism and the core-magnet mechanism can generally be mounted on magnetic or non-magnetic panels without special calibration.

Completely Sealed: All cases are sealed with neoprene gaskets to protect internal parts from dust, dirt, and water for extra-long, trouble-free operation. D-c movements and a-c iron-vane movement are accurate to within ± 2% of full scale value.

For complete information contact your nearby G-E Apparatus Sales Office or Distributor; or write for bulletin GEA-6678A, Section 582-31, General Electric Company, Schenectady 5, N. Y.



ACTUAL SIZE

Although they look bigger, these a-c and d-c units are actually 2½- and 3½-inch sizes. Mounting is interchangeable with JAN, MIL, and ASA (round) specifications.

Progress Is Our Most Important Product

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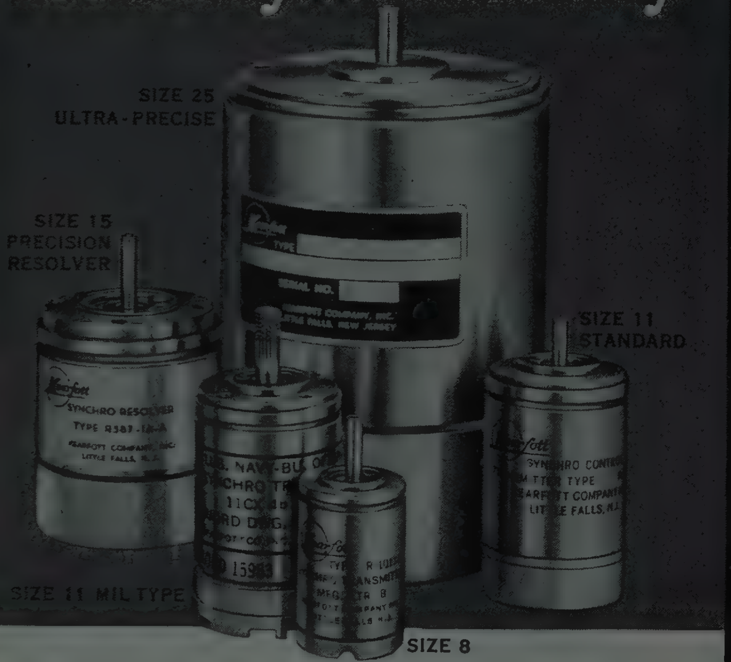
OPERATION upturn
Buy now for extra values
GENERAL ELECTRIC

Synchros...another Kearfott capability

accuracy...reliability



SYNCHROS FOR EVERY APPLICATION

Kearfott offers the widest range of synchros in the industry. Ruggedly constructed of corrosion-resistant materials, they give unequalled performance under every environmental condition. For best characteristics and reliability, specify Kearfott for all your synchro requirements. Here are a few typical models:

Size 8: .750″ x 1.240″. 1.75 oz. −54C to +125C. Available as transmitter, control transformer, resolver, and differential. Max. error from EZ: 10, 7 and 5 minutes.

Size 11 Standard: 1.062″x1.766″. 4 oz. −54C to +125C. Available as transmitter, control transformer, repeater, resolver and differential for 26v and 115v applications. Max. error from EZ: 10,7 and 5 minutes standard, 3 minutes in 4-wire configurations.

Size 11 MIL Type: Dimensions and applications same as above. Meets Bu. Ord. configurations: max. error from EZ: 7 minutes.

Size 15 Precision Resolver (R587):
With compensating network and transistorized booster amplifier, provides 1:1 transformation ratio, 0° phase shift. Max. error from EZ: 5 minutes.

Size 25 Ultra-Precise: 2.478″ x 3.187″. 45 oz.
Available as transmitter, differential, and control transformer. Max. error from EZ: 20 seconds arc.

Engineers: Kearfott offers challenging opportunities in advanced component and system developments.

Kearfott

GENERAL PRECISION EQUIPMENT CORPORATION
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Industrial Engineering Notes

(Continued from page 106A)

adopted at this time and instead proposed the following: The FCC should extend indefinitely the present temporary authorization for the broadcast transmission of reference and test signals during the vertical blanking interval on a permissive basis subject to certain restrictions set forth in the body of the comments. Copies of the comments may be obtained by writing EIA General Counsel William L. Reynolds, EIA headquarters, Washington, D. C.

GOVERNMENT

The so-called "Potter Resolution" (SJRes 106) to establish a commission of private citizens to investigate the utilization of radio and TV frequencies allocated to the agencies of the government has been approved by the Senate Interstate and Foreign Commerce Committee. The Commission would recommend, in a report to the President and to Congress within six months, more efficient use of the radio spectrum by these Federal agencies. . . . **The Senate Judiciary Subcommittee on Patents, Trademarks and Copyrights has released a report on the "impact of the patent system on research."** It was prepared for the subcommittee by Prof. Seymour Melman of Columbia University. The study deals with the increasing emphasis upon cooperative research conducted by large industrial and university research laboratories. One of the main conclusions is that, in the research area, the patent system has contributed little to the progress of science development. "Industrial firms will continue to enlarge their research in the useful arts as dictated by competitive needs, with or without patent privileges," Prof. Melman writes. "Henceforth," in his judgment, "the main impetus for the promotion of science and the useful arts will come, not from the patent system, but from forces and factors that lie outside that system.". . . **Legislation creating a single Federal Aviation Agency has been approved by the Senate and sent to the House for action.** The bill (S. 3880), embodying compromise language on the military's right to select missile and air base sites, was passed on a voice vote after four hours of debate. Author of the bill was Sen. A. S. Mike Monroney (D., Okla.) who accepted a compromise that would, in effect, authorize the President to resolve any stalemates. The new FAA bill repeals and rewrites the Air Commerce and Civil Aeronautics Acts, placing in the hands of a single administrator the power to regulate the use of navigable airspace; to acquire, establish, operate and improve air navigation facilities; to prescribe air traffic rules for all aircraft, and to conduct related research and development activities.

FCC

The FCC has given notice that it will conduct a fact-finding hearing sometime

(Continued on page 110A)

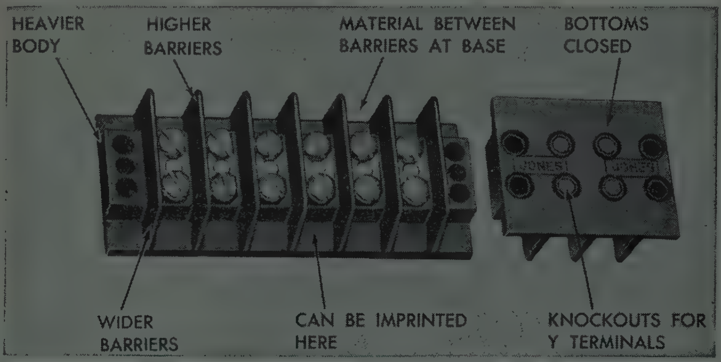
LAMBDA
REGULATED POWER SUPPLY

Guaranteed: around-the-clock performance for five years

Freedom from worry about major maintenance or extensive replacement for *five full years.* That's the guarantee given with every Lambda power supply—the first such guarantee in the electronics industry. It proves the point engineers keep making in preference studies: When operating conditions make dependability a "must," they specify Lambda... To check the full Lambda line yourself, send for the latest catalog.

LAMBDA POWER SUPPLIES

AT LAST—The IDEAL BARRIER TERMINAL STRIP



JONES 500 SERIES
LONGER—STURDIER

Wider and higher barriers for increased creepage distances. Closed bottoms for complete insulation. Material between barriers at the base adds to the strength and maintains the same creepage distance between contact to contact and contact to ground. Can be imprinted here. No insulating or marker strip required. Three series—540, 541 and 542 having the same terminal spacing as our 140, 141 and 142 series.

Complete listing in the new Jones No. 22 catalog. Write for your copy today.

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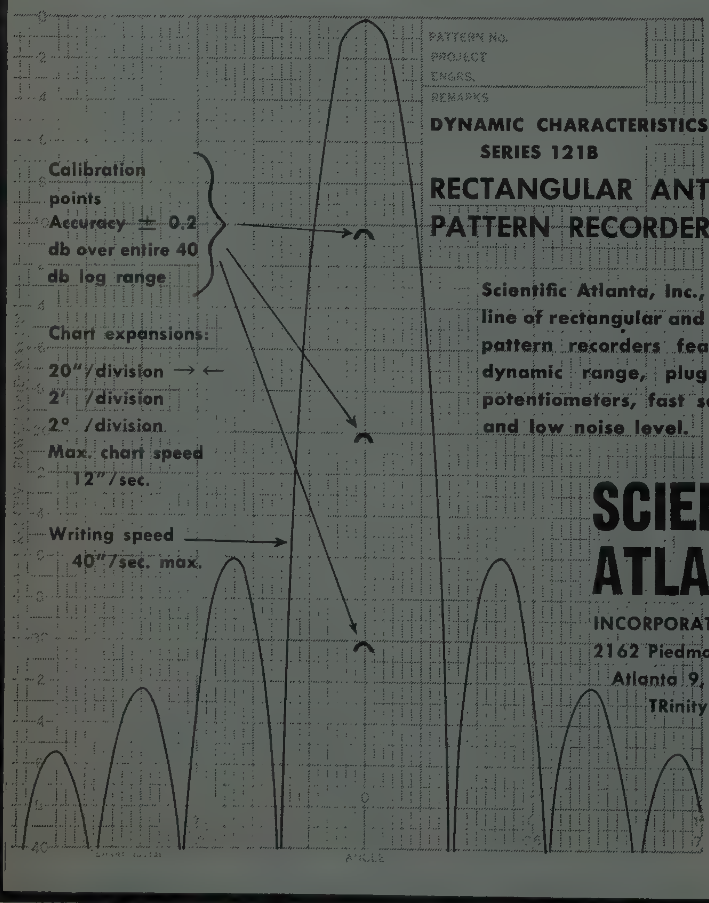


Calibration points
Accuracy ± 0.2 db over entire 40 db log range

Chart expansions:
20"/division
2' /division
2° /division
Max. chart speed 12"/sec.

Writing speed 40"/sec. max.

DYNAMIC CHARACTERISTICS
SERIES 121B
RECTANGULAR ANTENNA PATTERN RECORDER

Scientific Atlanta, Inc., offers a wide line of rectangular and polar antenna pattern recorders featuring 40 db dynamic range, plug-in balancing potentiometers, fast servo response and low noise level.

SCIENTIFIC ATLANTA
INCORPORATED
2162 Piedmont Road N. E.
Atlanta 9, Georgia
TRinity 5-7291

Industrial Engineering Notes

(Continued from page 108A)

after October 1 in Docket 11997, which concerns service allocation needs in that portion of the spectrum between 25-890 mc. Because of the great number of persons wishing to present evidence at such a fact-finding hearing, the name of each proposed witness and a detailed outline setting forth the substance of the evidence, both oral and written, that each such witness proposes to present must be submitted to the FCC on or before October 1. Based upon these statements it will be determined which witnesses will be invited to testify and what testimony and exhibits they will be asked to present. An original and four copies of each outline should be served on the General Counsel of the FCC, and each should be plainly entitled "Statement of Proposed Evidence for Docket No. 11997," the Commission said. The FCC urges that, wherever possible, all members of an industry group or association be represented by an industry spokesman or spokesmen. "When an industry is to be represented by an industry spokesman, any member of that industry group who desires to present his own witnesses will be required to show in detail the reasons why such additional representation is necessary, and what the additional evidence will be," the FCC said. . . . **On request by Aeronautical Radio, Inc., the FCC has further extended time to submit comments from July 15 to October 15, with rebuttal comments to be filed within 20 days thereafter, directed to the Commission's Further Notice for Proposed Rule Making in Dockets 11513, 11678, and 11654 regarding certain single-sideband operations. . . . The proposed shifting of all TV service to UHF bands is further from realization than when it was proposed by the FCC some four years ago, according to Robert T. Bartley, FCC Commissioner.** He gave this opinion during the recent Senate Commerce Committee hearings on the TV channel allocations situation. FCC Chairman John C. Doerfer did not contest Mr. Bartley's opinion but explained the agency is awaiting additional information from the Television Allocations Study Organization (TASO) which was formed by the industry to advise the Commission.

MILITARY ELECTRONICS

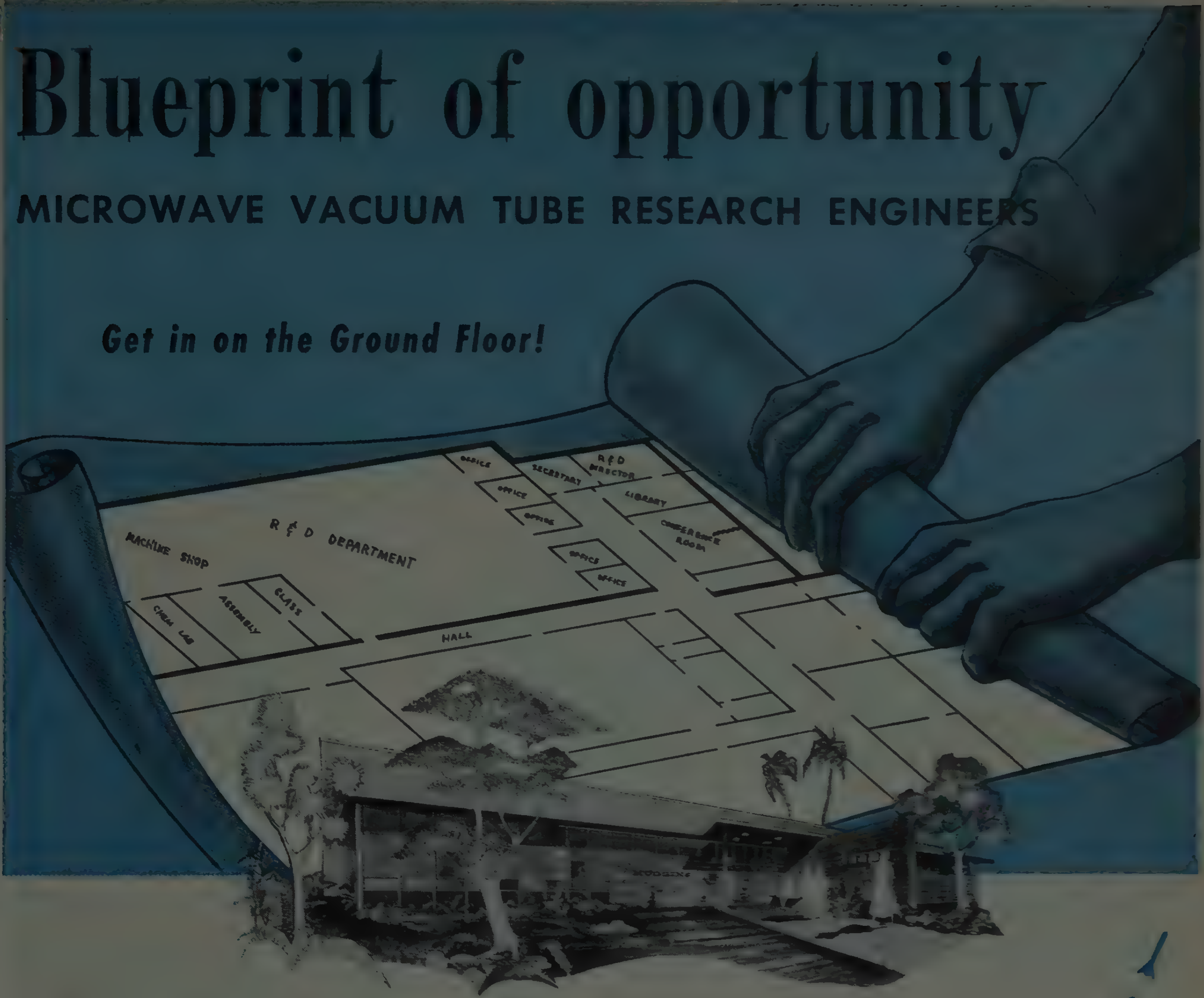
Edward E. Harriman has joined the Office of the Secretary of Defense as Scientific Advisor to William M. Holaday, Director of Guided Missiles. Mr. Harriman in addition to filling this newly created position will also serve as Executive Secretary of the Scientific Advisory Committee to the Director of Guided Missiles for ballistic missile programs, the Pentagon said. He was formerly with the Navy's BuOrd. . . . **The Army has awarded a $7.5 million contract to Lewyt Manufacturing Corp. for radio equipment.** The contract, let by the Signal Supply

(Continued on page 112A)

Blueprint of opportunity

MICROWAVE VACUUM TUBE RESEARCH ENGINEERS

Get in on the Ground Floor!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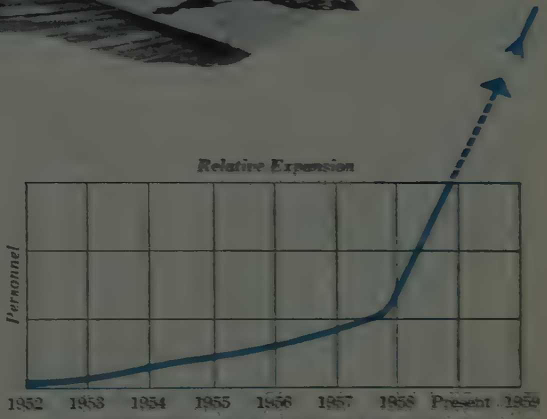
Our R & D group is now in the process of expanding as our production group has expanded in the past. Do you think that you can match our growth with yours? Our challenge to you is both a technical and personal one. The environment for creative thought is a part of our opportunity here.

Openings are available for Microwave Vacuum Tube Engineers, particularly those with advanced degrees or equivalent experience. There are rewarding assignments on research and development projects that await your inquiry.

HUGGINS LABORATORIES offers you:

- A Stock Participating Plan
- A Profit Sharing Plan
- A Career with a Challenge



HUGGINS IS E-X-P-A-N-D-I-N-G AND GROWING. HOW ABOUT YOU?

Work toward advanced degrees is encouraged. HUGGINS LABORATORIES is participating with Stanford University on its honors cooperative program for graduate study.

Our new modern laboratory is being completed in the heart of the San Francisco Peninsula's growing electronic complex. Our climatic, cultural and recreational environment is unsurpassed.

Write or wire your complete resume to: RICHARD A. HUGGINS, *President*

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CHOOSING THE RIGHT COMPUTER

An analog computer can be your basic tool for design, analysis, and control. You can solve a host of equations and simulate a variety of physical and chemical processes. You can even put the computer to work controlling the whole loop. You can do all these things quickly, conveniently and economically if you choose the right computer.

The Donner 3100 with non-linear equipment

WHAT ARE THE CRITERIA?

Functional versatility and operational convenience. In a great measure the new Donner 3100 combines these key characteristics at a better price than any other computer on the market. Here are some of the things that add up to functional versatility and operational convenience:

- ★ *Built-in simulation board in addition to regular patch board.*
- ★ *The functions of the amplifiers are unpromoted.*
- ★ *The Donner is designed for expansion. You can start with as few as ten amplifiers.*
- ★ *Electronic multipliers to accommodate non-linear terms.*
- ★ *Electronic transport delay generators to simulate "dead time."*
- ★ *24-point function generators for synthesis of arbitrary functions.*
- ★ *Diodes to create limiting, backlash, and dead zone effects.*
- ★ *A true operating console.*
- ★ *Two or more computers can be interconnected.*
- ★ *Accommodates extra amplifiers at the simulation board for other uses such as special transfer functions.*

Prices for this high accuracy, medium size analog computer begin at $16,775 for a computer with 20 chopper-stabilized amplifiers and 20 coefficient potentiometers. $18,550 purchases this computer with 30 amplifiers and 40 pots. Special OEM prices. We have prepared an eight page data file describing the new Donner 3100. Yours for the asking. Please address Dept. [illegible]

DONNER SCIENTIFIC COMPANY
CONCORD, CALIFORNIA

Industrial Engineering Notes

(*Continued from page 110A*)

Agency at Philadelphia, calls for GRC-81 radios which are used for communication by troop units in the field. . . . **A $60 million radio astronomy facility, known as the Naval Radio Research Observatory, is planned for construction in the mountains of West Virginia near Sugar Grove, the Navy has announced.** The site will house a giant radio telescope used in receiving electronic emissions from outer space. It will be operated under Navy management as a common service to the nation's scientific community and defense establishment.

STATISTICS

Factory production of both radio and television receivers in May declined from the April output of these items and was down somewhat from the level of May, 1957. Output during the first five months of this year was over the 1957 level in both radio and television production. TV production in May totaled 266,982 compared with 302,559 TV's made in April and 342,386 television units produced in May, 1957. The number of TV sets made with UHF tuners totaled 29,406 in May compared with 22,296 in April and 41,956 produced in May, 1957. Cumulative UHF tuner output this year totaled 172,915 compared with 282,083 such TV receivers in the same five-month period last year. Cumulative television production during the first five months of this year amounted to 1,790,840 compared with 2,178,361 TV's made during the like 1957 months. Radio receiver production in May totaled 654,803 including 185,616 auto receivers compared with 697,307 radios made in April which included 190,435 automobile radios and 627,620 radios made in May 1957, which included 196,135 automobile receivers. Cumulative radio receiver production during the first five months of this year totaled 4,186,869 including 1,229,186 auto receivers, compared with 6,098,951 radios made during the like five-month period in 1957, which included 2,418,618 auto receivers. . . . **Factory sales of transistors increased in May over the April level of sales.** Cumulative sales of these semiconductor devices during the first five months of this year increased substantially over the like 1957 period. Factory sales of transistors in May totaled 2,999,198 with a dollar value of $7,250,824 compared with 2,856,234 of these semiconductor devices valued at $7,025,547 sold in April and 2,055,000 units valued at $5,636,000 sold in May a year ago. Cumulative sales of transistors during the first five months of this year totaled 14,894,230 valued at $34,582,743 compared with 8,954,000 transistors with a value of $25,128,000 sold during the like five months last year.

FREQUENCY STANDARDS

PRECISION FORK UNIT
TYPE 50

Size 1" dia. x 3¾" H. Wght., 4 oz.*

Frequencies: 240 to 1000 cycles
Accuracies:—
Type 50 (±.02% at —65° to 85°C)
Type R50 (±.002% at 15° to 35°C)
Double triode and 5 pigtail parts required
Input, Tube heater voltage and B voltage
Output, approx. 5V into 200,000 ohms

*3⅛" high
400 - 1000 cy.

FREQUENCY STANDARD
TYPE 50L

Size 3¾" x 4½" x 5½" High
Weight, 2 lbs.

Frequencies: 50, 60, 75 or 100 cycles
Accuracies:—
Type 50L (±.02% at —65° to 85°C)
Type R50L (±.002% at 15° to 35°C)
Output, 3V into 200,000 ohms
Input, 150 to 300V, B (6V at .6 amps.)

PRECISION FORK UNIT
TYPE 2003

Size 1½" dia. x 4½" H. Wght. 8 oz.*

Frequencies: 200 to 4000 cycles
Accuracies:—
Type 2003 (±.02% at —65° to 85°C)
Type R2003 (±.002% at 15° to 35°C)
Type W2003 (±.005% at —65° to 85°C)
Double triode and 5 pigtail parts required
Input and output same as Type 50, above

*3½" high
400 to 500 cy.
optional

FREQUENCY STANDARD
TYPE 2005

Size 8" x 8" x 7¼" High
Weight, 14 lbs.

Frequencies: 50 to 400 cycles
(Specify)
Accuracy: ±.001% from 20° to 30°C
Output, 10 Watts at 115 Volts
Input, 115V. (50 to 400 cycles)

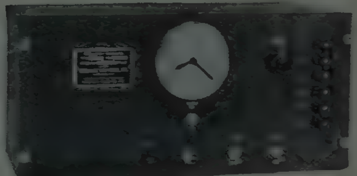
FREQUENCY STANDARD
TYPE 2007-6

NEW

TRANSISTORIZED, Silicon Type
Size 1½" dia. x 3½" H. Wght. 7 ozs.

Frequencies: 400 — 500 or 1000 cycles
Accuracies:
2007–6 (± .02% at —50° to +85°C)
R2007–6 (±.002% at +15° to +35°C)
W2007–6 (±.005% at —65° to +125°C)
Input: 10 to 30 Volts, D. C., at 6 ma.
Output: Multitap, 75 to 100,000 ohms

FREQUENCY STANDARD
TYPE 2121A



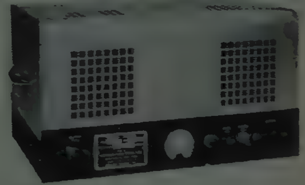
Size
8¾" x 19" panel
Weight, 25 lbs.
Output: 115V
60 cycles, 10 Watt
Accuracy:
±.001% from 20° to 30°C
Input, 115V (50 to 400 cycles)

FREQUENCY STANDARD
TYPE 2001-2

Size 3¾" x 4½" x 6" H., Wght. 26 oz.

Frequencies: 200 to 3000 cycles
Accuracy: ±.001% at 20° to 30°C
Output: 5V. at 250,000 ohms
Input: Heater voltage, 6.3 - 12 - 28
B voltage, 100 to 300 V., at 5 to 10 ma.

FREQUENCY STANDARD
TYPE 2111C



Size, with cover
10" x 17" x 9" H.
Panel model
10" x 19" x 8¾" H.
Weight, 25 lbs.
Frequencies: 50 to 1000 cycles
Accuracy: (±.002% at 15° to 35°C)
Output: 115V, 75W. Input: 115V, 50 to 75 cycles.

ACCESSORY UNITS
for TYPE 2001-2

L—For low frequencies multi-vibrator type, 40-200 cy.
D—For low frequencies counter type, 40-200 cy.
H—For high freqs, up to 20 KC.
M—Power Amplifier, 2W output.
P—Power supply.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government departments, armed forces—where maximum accuracy and durability are required.

WHEN REQUESTING INFORMATION
PLEASE SPECIFY TYPE NUMBER

American Time Products, Inc.

Watch Master
Timing Systems

Telephone: PLaza 7-1430

580 Fifth Ave., New York 36, N. Y.

High Quality French products

CAPACITOR KNOBS

- Uncoupling Knobs Types : CB II N and CB II P

SPECIFICATION MIL C 10 950 A

C	$\frac{\Delta C}{C\Delta\theta}$	Stability
$12 \leqslant C \leqslant 1000$	$0 \leqslant \frac{\Delta C}{C\Delta\theta} < 70.10^{-6}$	$\pm (5.10^{-4} \pm .1$ pf)

- Mica Capacitors "STABILIDISC"

C	$\frac{\Delta C}{C\Delta\theta}$	Stability
$12 \leqslant C \leqslant 1000$	$15.10^{-6} \leqslant \frac{\Delta C}{C\Delta\theta} \leqslant 45.10^{-6}$	(high stability) $\pm (3.10^{-4} \pm .1$ pf)

The high performance of the capacitors results from being hand-made

The same high performance is guaranteed in the large series

Write for samples :

TRY THEM AND VERIFY THE QUALITY — AND THE PRICE

use a good condenser and you won't waste your money on repairs

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SOFEL PARIS

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specialists

COMPLETE LINE for every Military and Special purpose . . . in PRODUCTION QUANTITIES . . . or CUSTOM DESIGNED to your specific requirement.

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INSTRUMENTS, INC.

100 Industrial Road, Addison, Ill., Phone Kingswood 3-6444

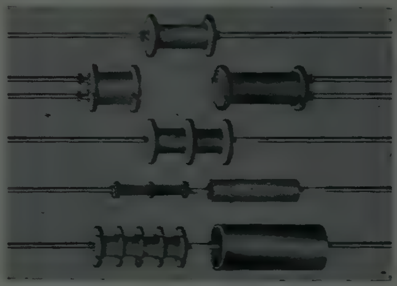
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 40A)

Epoxy Bobbins With Leads and Shells

Thor Ceramics, Inc., Department K, 225 Belleville Ave., Bloomfield, N. J., announces a new line of epoxide resin bobbins with leads and shells for encapsulation. Their adhesive qualities make these miniature forms suitable for hermetically sealing wire-wound resistors.



These are fabricated from thermosetting epoxide resin, which has excellent physical and electrical characteristics, high tensile strength, low water absorption. and a dielectric constant of 3.70 at 60 cps and low loss factor of 0.009 at 60 cps. They operate to a maximum temperature of 150°C. Leads may be specified for different lengths and od.

Resistor Bulletin

Ultronix, Inc., 116 S. Bayshore Blvd., San Mateo, Calif., has released a four page bulletin describing their new line of fully encapsulated precision wire-wound resistors which feature unusual stability, extremely low temperature coefficient, and close tolerance.

The bulletin contains actual size illustrations of the various models as well as technical specifications and dimensional schematics. For your free copy, please write to the firm.

Transformer Brochure

The Eisler Transformer Co., Inc., 16 N. Salem St., Dover, N. J. (a division of Eisler Engineering Co., Inc.) has just issued a four page brochure showing part of their new facilities and different types of transformers constructed by the company. For a free catalog write to the firm.

Chart Viewer

A new oscillographic recording chart viewer developed by **Sanborn Co., Industrial Div.,** 175 Wyman St., Waltham 54, Mass., provides variable chart drive speeds from 15 inch/minute to 100 feet/minute, and accepts charts up to 16 inches wide and 200 feet long. The viewer is designed especially for use with Sanborn 1- to 8-

(Continued on page 116A)

An advanced concept

The Singer Manufacturing Company announces the formation of its Military Products Division, which through its three functional units, Haller, Raymond & Brown, Inc., Diehl Manufacturing Company, and Singer Bridgeport Division, can efficiently handle complex electro-mechanical and electronic programs from concept to completion.

SINGER *

THE SINGER MANUFACTURING COMPANY
Military Products Division
149 BROADWAY, NEW YORK 6, N. Y.

*A TRADEMARK OF THE SINGER MANUFACTURING COMPANY

MILITARY PRODUCTS DIVISION

FREE - - - Revised IERC Heat-Dissipating Tube Shield Guide!

MORE THAN 1,200 ELECTRON TUBE AND SHIELD COMBINATIONS FOR IMPROVED ELECTRON TUBE RELIABILITY ADDED TO REVISED EDITION. Thousands of original IERC Guides are in daily use everywhere! Newest edition is sent FREE on request. Over 25 pages of easy, thoughtfully referenced listings and fold-out spread of photos designed for fast familiarization and accurate use of the IERC Guide. Latest IERC Heat-dissipating Tube Shields are included—help you select proper shields for new design and retrofitting applications. You won't want to be without this valuable information package if you're designing for maximum equipment reliability—so easy to achieve with IERC Heat-dissipating Electron Tube Shields for effective electron tube cooling and retention under severest shock and vibration environments!

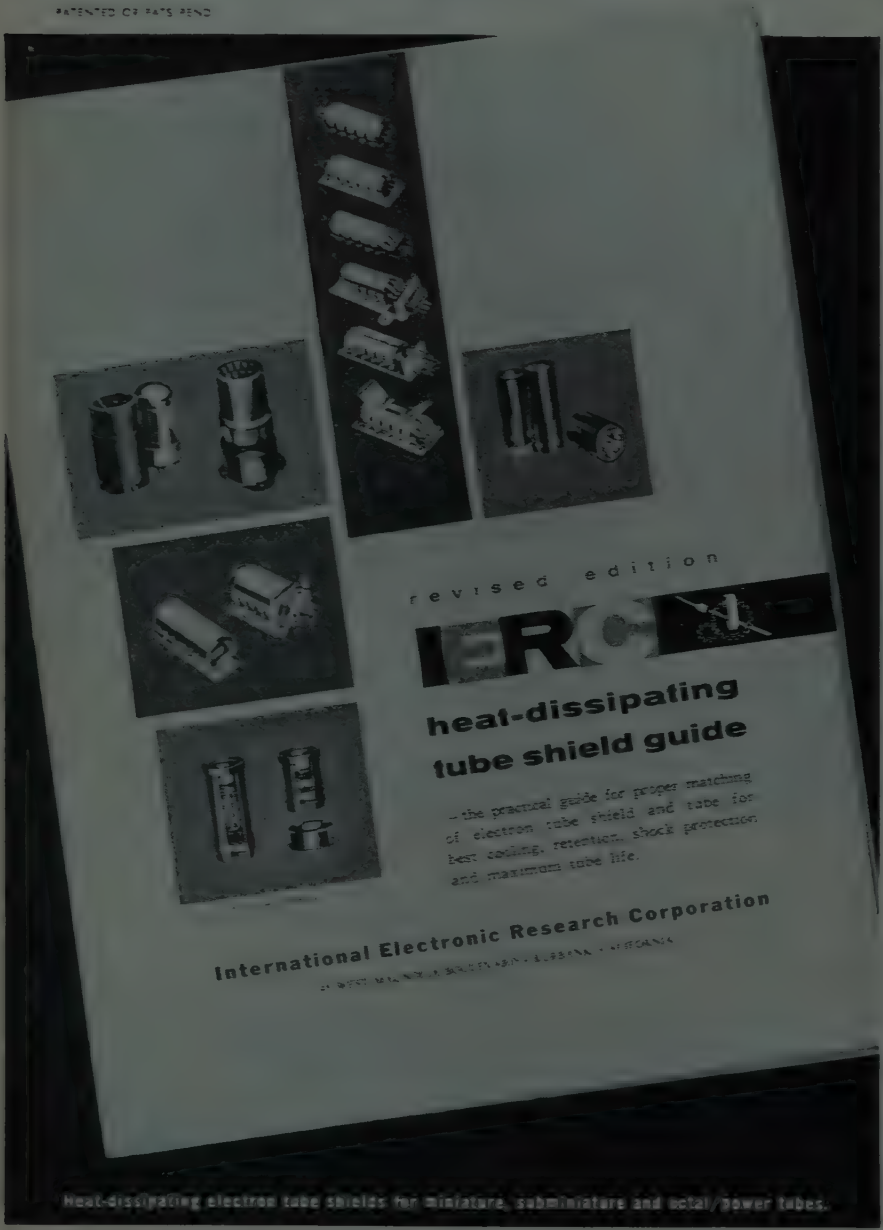
For a free copy, write on company letterhead to: Dept. TSG,

IERC

International Electronic Research Corporation

145 West Magnolia Boulevard, Burbank, California

PATENTED OR PATS PEND


revised edition
IERC
heat-dissipating
tube shield guide
—the practical guide for proper matching of electron tube shield and tube for best cooling, retention, shock protection and maximum tube life.
International Electronic Research Corporation

Heat-dissipating electron tube shields for miniature, subminiature and octal/power tubes.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 114A)

channel regular or the new translucent Permapaper charts, and will accept other types of charts as well.

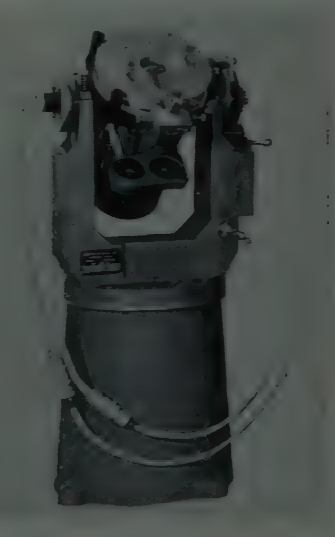
SANBORN MODEL 276 VIEWER
FOR OSCILLOGRAPHIC CHART RECORDINGS

The Model 276 Chart Viewer has a direction-reversing switch combined with the speed control to allow rewinding at any time, and automatic braking to prevent supply roll overrun when speed is reduced. The chart table is finished in black to provide the best viewing of translucent Permapaper charts, and is equipped with a transparent plastic cursor to facilitate examination and correlation of multi-channel recordings. Cursor slides left to right and pivoted at one end to allow rotation through a small angle.

Over-all dimensions are $36 \times 22\frac{1}{2} \times 7\frac{1}{4}$ inches high and total weight is approximately 25 pounds. Controls and equipment include main power switch, direction/speed selector control, pilot light and fuse. Further information is available on request from the firm.

Gyro Test Turntable

Sterling Precision Corp., 17 Matinecock Ave., Port Washington, L. I., N. Y., is manufacturing a T-806 Precision Gyro Test Turntable, a high precision, rugged equipment especially designed for testing low-drift gyros in either open or closed loop. Easy accurate tilting permits polar axis drift tests as well as vertical, inverse vertical, and horizontal axis drifts tests,



(Continued on page 118A)

TUNG-SOL POWER TRANSISTORS IMPROVED THREE WAYS BY:

NEW Cold-Weld SEAL

Tung-Sol's new true cold-weld seal represents a major advance in transistor technology. An exclusive Tung-Sol development, cold-weld sealing increases TO-3 outline package efficiency and brings designers a threefold bonus in over-all transistor performance.

Improved thermal qualities. The cold-weld process produces a hermetic, copper-to-copper seal and makes possible a 100% copper transistor with thermal properties superior to previous high power types.

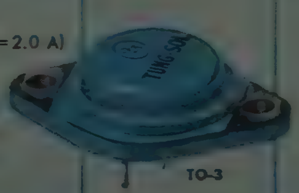
Improved reliability. Cold-weld encapsulation eliminates heat damage, "splash", and heat-caused moisture that can impair transistor performance.

Longer efficient life. Even through temperature fluctuations that cause "breathing", the cold-weld seal stays vacuum-tight, moisture-proof—result of actual integration of the copper molecules during sealing.

Tung-Sol power switches with the new cold-weld seal withstand the most rigid combination of tests given any transistor—the 100 psi "bomb" immersion test and the critically sensitive Mass Spectrometer leak test. Further, they meet all military environmental requirements. For full data on the improved Tung-Sol types . . . to fill any transistor need, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

THESE TUNG-SOL HIGH POWER (TO-3 OUTLINE) TRANSISTORS FEATURE THE NEW, COLD-WELD SEAL

Type	BV_{CES} ($V_{BE}=+1.0$v) Volts (Min)	BV_{CEO} ($I_B=0$) Volts (Min)	h_{FE} ($I_C=1.0$ A)	h_{FE} ($I_C=2.0$ A)
2N378	−40	−20	50	30
2N379	−80	−40	50	30
2N380	−60	−30	70	50
2N459	−105	−60	50	30



TO-3

IMPROVED SPECIFICATIONS OF TUNG-SOL COLD-WELDED HIGH POWER TRANSISTORS.

Collector Dissipation @ 25°C*...50 Watts
Collector Dissipation @ 55°C*...25 Watts
Thermal Resistance.............1.2° C/Watt Max.
I_{CBO} @ $V_{CB}=-25$v T = 25°C...0.5 Ma Max.
I_{CBO} @ $V_{CB}=-25$v T = 85°C...7.5 Ma Max.
Storage Temperature..........−55 to +100°C

*Mounting base temperature

TUNG-SOL

TUBE PRODUCTION IS A SCIENCE AT VARIAN

Special aptitude test for metals

This man is vaporizing a test sample from an incoming metals shipment in a spectrograph to determine its composition. And spectral readings, accurate to .001%, will show whether or not it meets Varian's high quality standards. Copper for components, nickel alloy for cathodes, glass sealing alloys, all are critically checked and controlled before and during manufacture to guarantee that the completed **Varian Tubes** will perform as specified.

This is the kind of quality control that has made **Varian Tubes** "Standard" for all microwave installations. Over 100 of these tubes are described and pictured in our latest catalog. Write for your copy today.

THE MARK OF LEADERSHIP

VARIAN associates
PALO ALTO 2, CALIFORNIA
Representatives thruout the world

KLYSTRONS, TRAVELING WAVE TUBES, BACKWARD WAVE OSCILLATORS, LINEAR ACCELERATORS, MICROWAVE SYSTEM COMPONENTS, R.F. SPECTROMETERS, MAGNETS, MAGNETOMETERS, STALOS, POWER AMPLIFIERS, GRAPHIC RECORDERS, RESEARCH AND DEVELOPMENT SERVICES

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 116A)

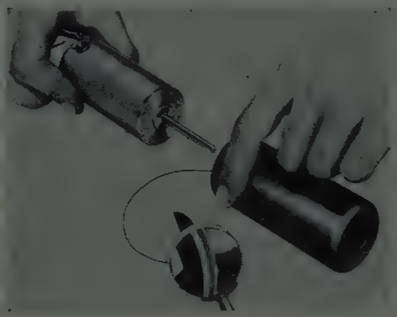
all without changing the position of the gyro on the turntable. Turntable drive is by smooth, precision geared servo-motor, with alternative step rate drive. Basic accuracy of the master precision rotation dial is 2 seconds of arc. The gearing and the slip rings are completely enclosed. There is a two-speed synchro table rotation transmitting system for remote recording.

Significant dimensions are: turntable, 14 inches; overall diameter, 24 inches; height 54 inches. Total weight is 900 pounds.

For further information contact the firm.

3-Layer Motor Shield

A new Netic Co-Netic magnetic shielding can for automatic recording or programming systems and other small motor applications has been developed by **Magnetic Shield Div., Perfection Mica Co.,** 1322 No. Elston Ave., Chicago 22, Ill. The shield attenuates both high and low frequencies at high and low intensities, permitting miniaturization of servo, synchro and other small motor systems by confining the motor's radiated magnetic and electrostatic noise. The Netic layer is placed adjacent to the motor for high level shielding and the 2 Co-Netic layers outside to assure a minimum radiation of the interfering field. This hydro-formed 3-layer construction including both high and low level shielding is said to make the seamless can three times as effective as previous motor shields. The shield is nonshock sensitive, non-retentive and requires no periodic annealing.



Audio Preamplifier

Electronic Systems Engineering Co., 903 Cravens Building, Oklahoma City, Okla., announces the Limpander (Limiter-Expander) Model LE-2, audio preamplifier with new high speed, non-feedback, automatic gain control that incorporates a unique background noise squelching system. High impedance input, and outputs at low level as well as 600 ohms (high level), facilitates easy incorporation in existing installations. The limiter portion of the amplifier has a time constant of 50

(Continued on page 122A)

New Transistorized

FREQUENCY DISCRIMINATOR AND SERVO DRIVEN CORRECTION LOOP

±0.5 ~ accuracy

AIRCRAFT ENGINE

VARIABLE RATIO ENGINE TRANSMISSION

MAIN ALTERNATOR

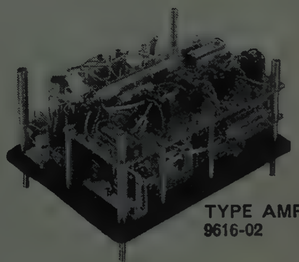
Oster®

Designed for controlling a **LYCOMING** variable ratio engine transmission which drives a typical aircraft alternator at constant speed.

- ±0.125% (400 ±0.5 cycles) accuracy.
- —55°C to +125°C ambient temperature range.
- Smaller, lighter, less complex through use of semiconductors.

TYPE 24PG-6954-02

AUXILIARY ENGINE DRIVEN ALTERNATOR



TYPE AMP-9616-02

FREQUENCY DISCRIMINATOR AND SPECIALIZED SERVO AMPLIFIER

TYPE STU-6003-01

SERVO TORQUE UNIT WITH STABILIZING GENERATOR FEEDBACK

Other types of systems can be designed to your specification. For more information contact the Oster office nearest you.

Burton Browne Advertising

Other products include servos, synchros, resolvers, motor-gear-trains, AC drive motors, DC motors, servo mechanism assemblies, reference and tachometer generators, servo torque units, actuators and motor driven blower and fan assemblies.

John Oster **MANUFACTURING CO.**
Your Rotating Equipment Specialist
Avionic Division
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Phone: ESsex 3-2361

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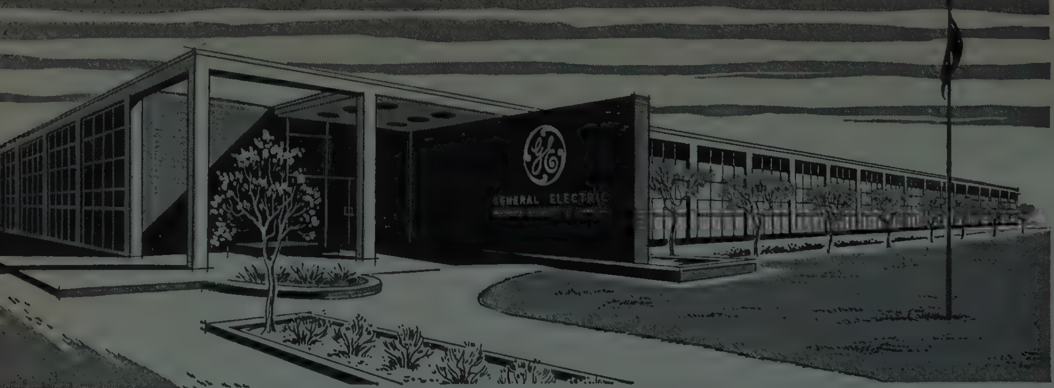
5333 So. Sepulveda Blvd.
Culver City, California
Phones: EXmont 1-5742
TExas 0-1194
TWX S. Mon 7671

Engineers For Advanced Projects: Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.



The G-E Power Tube Microwave Laboratory is located at Stanford Industrial Park, Palo Alto, California where it was one of the Park's pioneer installations. Its staff of scientists and engineers has the advantage of technical exchange with Stanford University faculty and research staffs, as well as with General Electric's own Research and General Engineering Laboratories.

RADAR CAPABILITY BROADENED BY HIGH-
TUBES DEVELOPED AT GENERAL ELECTRIC

DEVELOPMENT of advanced high-power, pulsed traveling-wave tubes at the Power Tube Department's Microwave Laboratory at Palo Alto, California, is contributing substantially to the broadening of radar frequency ranges. Vital accomplishments provided are: high pulse powers over wide instantaneous bandwidths; periodic permanent-magnet focusing; novel, light-weight, rugged tube structures. In addition to systems-oriented work at X band, developments are progressing at L, S, C, and K bands.

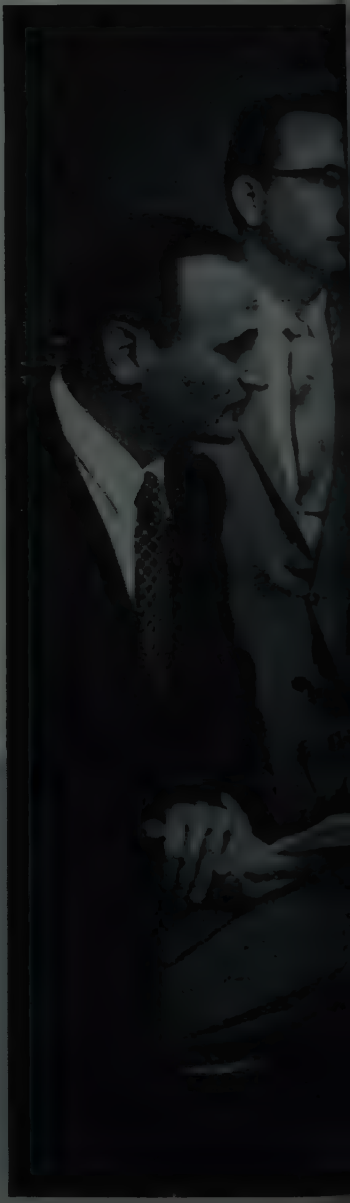
Traveling-wave tube pioneering is only one of a broad range of microwave activities being conducted at the G-E Microwave Laboratory. The Laboratory's fields of activities are applied research, advanced development, and product design in microwave tubes and microwave techniques. All development work is done with an eye to practical, economical manufacture — thus minimizing the time lapse between prototype development and quantity production—and to the realistic tube needs of future microwave equipment. Technical inquiries pertaining to advanced microwave tube development invited. *Power Tube Department, General Electric Company, Schenectady, New York.*

* * *

Professional opportunities available for engineering and scientific personnel. Inquiries invited.

Progress Is Our Most Important Product

GENERAL ELECTRIC

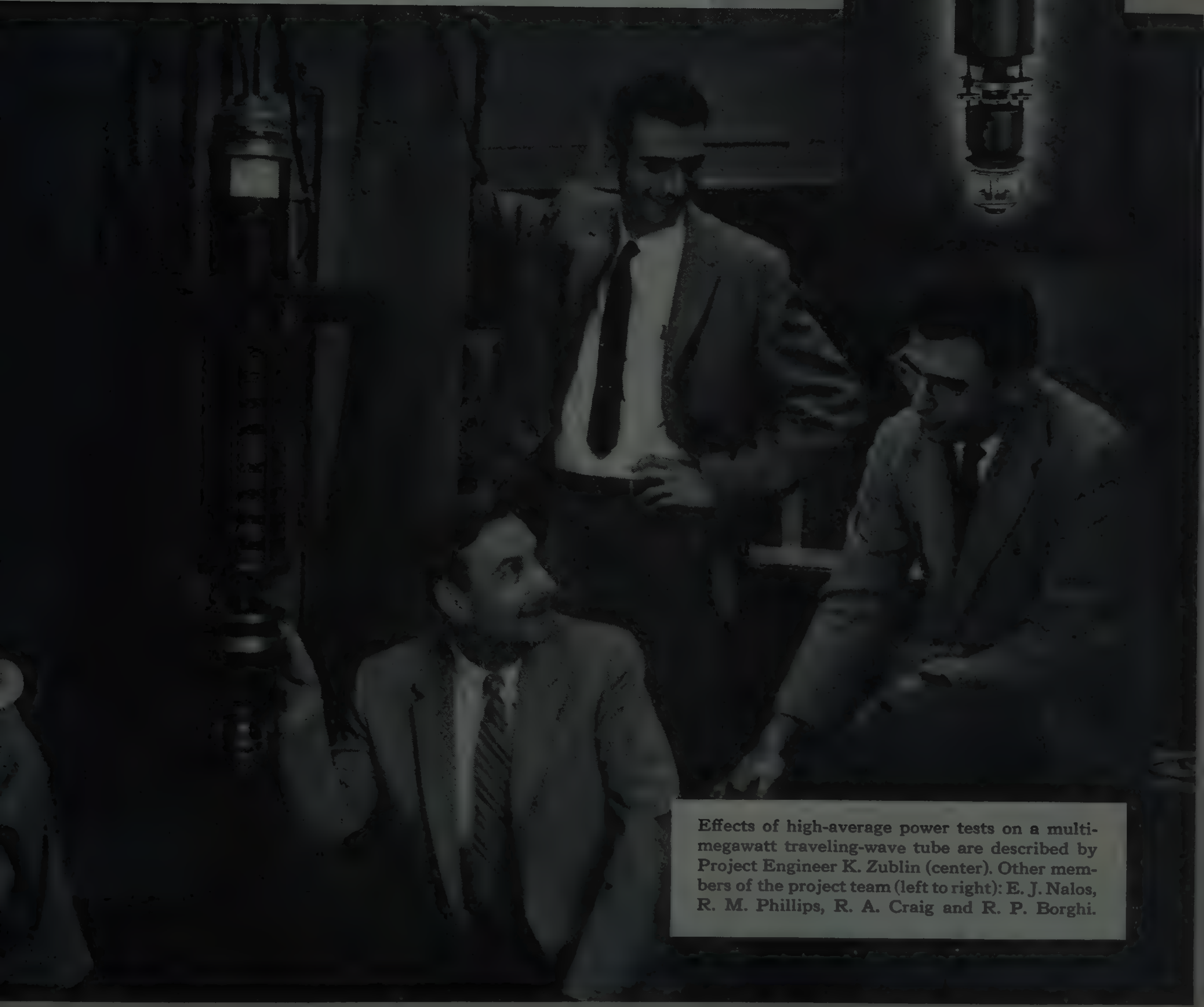


Extensive development work in the following classes of tubes is a continuing activity of the G-E Microwave Laboratory's staff of scientists, engineers and technical personnel.

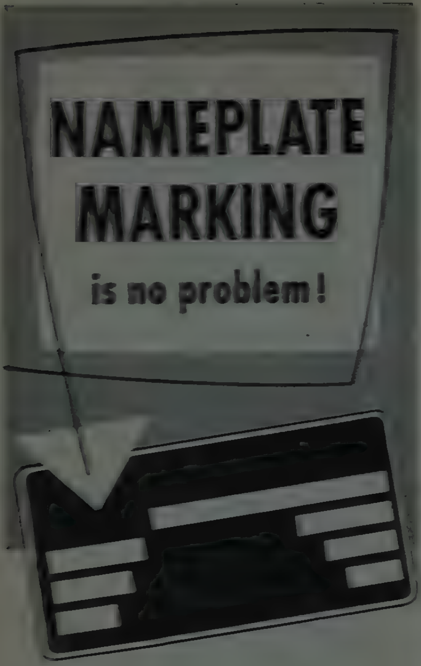
- Pulse klystron power amplifiers
- CW klystron amplifiers
- High-power pulsed TWT amplifiers
- Medium-power CW TWT amplifiers
- Low-noise, broadband TWT amplifiers
- Super-power klystrons
- Voltage-tunable oscillators
- High-power duplexers
- Microwave filters
- Frequency multiplier TWT amplifiers

POWER TRAVELING-WAVE
MICROWAVE LABORATORY

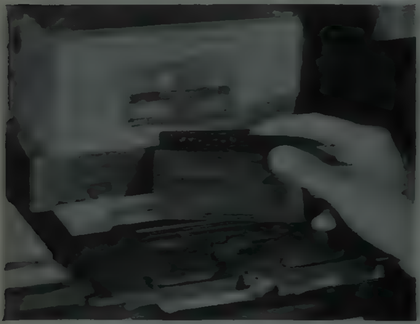
Typical of traveling-wave tubes being developed at the G-E Microwave Laboratory is this S-band tube which has operated successfully at the 2-megawatt pulse output level with 30 db gain.



Effects of high-average power tests on a multi-megawatt traveling-wave tube are described by Project Engineer K. Zublin (center). Other members of the project team (left to right): E. J. Nalos, R. M. Phillips, R. A. Craig and R. P. Borghi.


NAMEPLATE MARKING is no problem!

All panels of the plate are marked simultaneously through the unique "roll principle" of marking employed by the Matthews' No. 222 Machine. Interchangeable steel type characters contained in the nesting fixture impress the marking in perfect alignment and uniform depth.



Matthews' complete line of nameplate marking equipment includes such versatile units as the automatic solenoid controlled No. 222 Machine; the No. 223 manually operated model; and the No. 4 Detail Machine for limited production. These and many others are available from the "complete line" at Matthews.

Write today for Matthews' Nameplate Marking Brochure.

JAS. H. MATTHEWS & CO.
3922 Forbes Ave., Pittsburgh 13, Pa.
Offices in Principal Cities
WRITE, CALL OR TWX PG 424

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 113A)

microseconds on attack and 20 milliseconds on release. "Constant Amplification" is accomplished without the excessive distortion of clipper circuits. The high speed background noise squelching system makes it possible to use high gain, consonant amplifying, limiting in noise filled rooms such as control towers, reception booths, etc.

The amplifier can be applied effectively to public address systems with special benefits for outdoor installations that must override wind and crowd noise.

The LE-2 is especially designed to function as an automatic gain control system for tape recorders. It is particularly suited for recording unrehearsed conversations and conferences where it is impractical to use conventional gain monitoring techniques. The 600 ohm output has sufficient power to drive a speaker directly. One unit can serve for limiting on recordings, and for limiting or expanding on playback. Noise suppression capabilities make 60 db of automatic audio control practical.

Voltages to Digits Converter

The new model M-1 incremental multiverter, designed by **Packard-Bell Computer Corp.**, 1905 S. Armacost Ave., Los Angeles 25, Calif. converts voltages to digits in a single high information channel at rates as high as 200,000 conversions per second. The M-1 will literally follow a single function on an incremental basis. A digital number is always present in the output register, with the change being entered every five microseconds (to accuracies of 0.01 per cent). The counter used accepts three types of input: $-1, +1$, and 0 (or no change). Variations of the basic

(Continued on page 124A)

Electrically Conductive Cloth

A New Engineering Material for Many Applications in Electronics

SUGGESTED USES:
RF SHIELDING
RADAR REFLECTION
MICROWAVE GASKETING
WARNING SYSTEMS
ATTENUATORS
STATIC DISCHARGE

Buy it by the yard and sew it to shape on any sewing machine. Or, have us sew it for you.

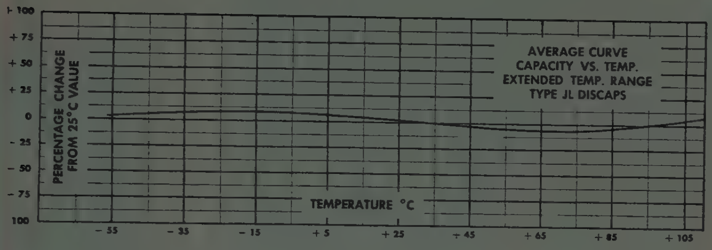
WRITE OR PHONE

Swift
Textile Metalizing & Laminating Corp.
10 Love Lane, Hartford 1, Conn.
JAckson 2-1181

RMC

brings you "temperature stable" Discaps

TYPE JL DISCAPS



RMC
800
RMC
.0018
RMC
.0039

Type JL DISCAPS are especially designed for applications requiring a minimum capacity change as temperature varies between −60°C and +110°C. The maximum change between these extremes is only ±7.5% of capacity at 25°C.

With a standard working voltage of 1000 V.D.C., Type JL DISCAPS are ideal cost saving replacements for paper or general purpose mica capacitors.

Write on your letterhead for additional data.

SPECIFICATIONS

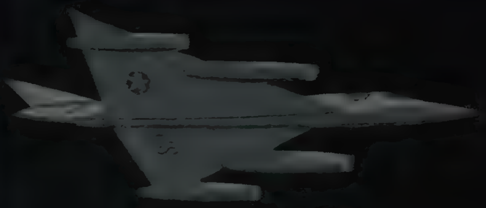
LIFE-TEST: As per EIA-RS-198
POWER FACTOR: 1.5% Max. @ 1 KC (initial)
POWER FACTOR: 2.5% Max. @ 1 KC (after humidity)
WORKING VOLTAGE: 1000 V.D.C.
TEST VOLTAGE (FLASH): 2000 V.D.C.
LEADS: No. 22 tinned copper (.026 dia.)
INSULATION: Durez phenolic—vacuum waxed
INITIAL LEAKAGE RESISTANCE: Guaranteed higher than 7500 megohms
AFTER HUMIDITY LEAKAGE RESISTANCE: Guaranteed higher than 1000 megohms
CAPACITY TOLERANCE: ±10% ±20% at 25°C

RMC uses the General Radio type 716-C Capacitance Bridge as the standard of capacity and power factor for all Hi K materials. The standard test frequency is 1000 cycles for all capacity and power factor readings. Capacity and power factor readings at any other frequency can not be guaranteed.

DISCAP
CERAMIC
CAPACITORS

RMC

RADIO MATERIALS COMPANY
A DIVISION OF P. R. MALLORY & CO., INC.
GENERAL OFFICE: 3325 N. California Ave., Chicago 18, Ill.
Two RMC Plants Devoted Exclusively to Ceramic Capacitors
FACTORIES AT CHICAGO, ILL. AND ATTICA, IND.



new from
CHICAGO STANDARD

HERMETICALLY SEALED
400 CYCLE
TRANSFORMERS

IN
MILITARY STANDARD
CASES
in stock for
immediate delivery

POWER TRANSFORMERS—TF4SX03* (plate and filament)
FILTER REACTORS—TF4SX03*
FILAMENT TRANSFORMERS—TF4SX01*

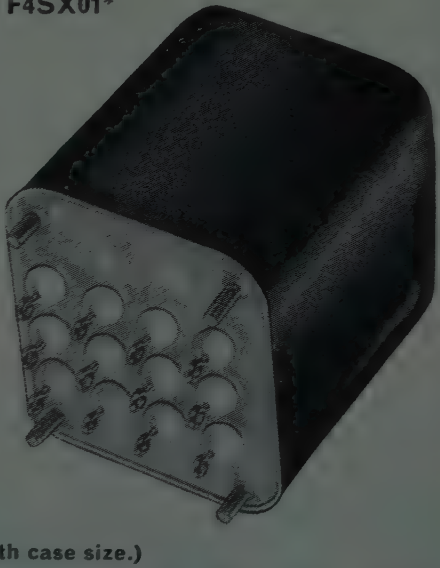
These transformers are designed and built in accordance with MIL-T-27A, Grade 4, Class S (85°C. ambient, 45°C. rise), operating temperature and life expectancy X (10,000 hours, minimum). Maximum operating altitude 70,000 feet. Schematics permanently silk-screened on one-piece drawn steel case.

For complete details on these new stock transformers write for the new Chicago Catalog CT3-57.

*(indicate letter designations that vary with case size.)

CHICAGO STANDARD TRANSFORMER CORPORATION

3504 Addison Street • Chicago 18, Illinois
Export Sales: Roburn Agencies, Inc. 431 Greenwich St., New York 13, N.Y.



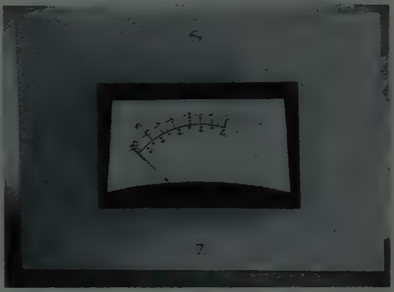
(Continued from page 122A)

M-1 can produce square roots or quotients in the conversion process. The number of places carried in the conversion can be varied to permit the interchange of speed and accuracy. The Multiverter is completely transistorized, small in size, and low in power requirements.

VU Meters

VU meters that meet American Standard C16.5–1954, but occupy at least 15 per cent less panel space than comparable units, are now being offered by **Assembly Products, Inc.,** Chesterland, Ohio.

These VU meters are being supplied in the new model 561 housing that exposes only the indicating area. The remaining 30 per cent of the meter is mounted behind the panel.



For easier reading without strain, the dial of the new meter not only has the usual buff background and red numerals, but it is also tilted back 6 degrees from the horizontal so that glare is reflected upward. As a further aid to visual comfort, the meter may be illuminated from behind the panel, through a strip of translucent plastic across the top of the dial section.

In accordance with the Standard, the new meter has a response time for a step change of 0.3-second, ±10 per cent. Overshoot is 1 to 1.5 per cent. Calibration follows circuit conditions as defined in the Standard.

When this VU meter is used on a conventional 600-ohm line, a constant impedance attenuator is matched to the meter's 3900 ohms and a 3600-ohm series resistor is employed.

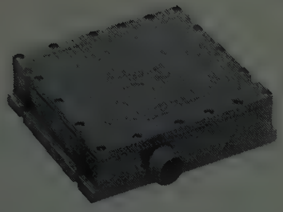
Strain-Gage Power Supply

Neff Instrument Corp., 2211 E. Foothill Blvd., Pasadena, Calif., introduces their new 2–200 Transistorized Strain-Gage Power Supply. This unit provides 0–15 volts at 0–5 amperes with less than 1 mv drift over a 24 hour period at constant temperature, and less than 0.001 per cent deg. F change with temperature variations. A 10 per cent change in line voltage will produce a change of less than 2 mv in output, while a 1 ampere change in load current will produce less than 1 mv change in output. Ripple is less than 1 mv peak to peak under all conditions of load.

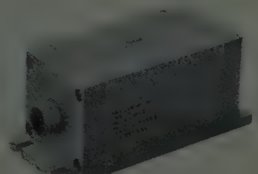
(Continued on page 126A)

DESIGNED TO FLY

Especially designed to meet the rigid size and weight requirements of airborne instrumentation, Statham's new strain gage carrier amplifiers are transistorized throughout. Operating from normally available 28-volt DC excitation, these units supply excitation to any strain gage transducer of desired range, amplifying and demodulating the transducer's low-level signals to provide an output of from 0 to 5 volts DC. When you require unprecedented accuracy and reliability in the amplification of signals from your strain gage instrumentation, specify a Statham strain gage amplifier.



Model CA3 Strain Gage Amplifier



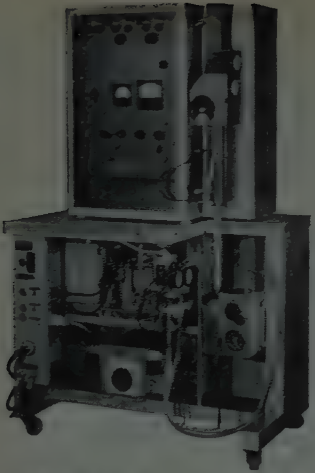
Model CA5 Strain Gage Amplifier

EXCITATION: 28 volts DC, ±5%
OUTPUT: 0-5 volts DC
FREQUENCY RESPONSE: Flat from 0 up to 2000 cps
NON-LINEARITY AND HYSTERESIS: ±½%
OPERATING TEMPERATURE: −65° to +165°F.
OUTPUT IMPEDANCE: 10K ohms (100K recommended load)
WEIGHT: 14.5 ounces, approximately

For complete technical data, write to:

See you at Booth 944
I.S.A. Show, Sept. 15-19

Statham
INSTRUMENTS, INC.
12401 W. Olympic Blvd., Los Angeles 64, California



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For brochure giving details and specifications, write:

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NEWS
New Products

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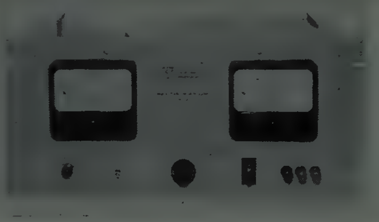
(Continued from page 124A)



To protect the end instruments, the circuit design prevents failure voltages of greater than 20 volts. Even a direct short will not damage the power supply itself.

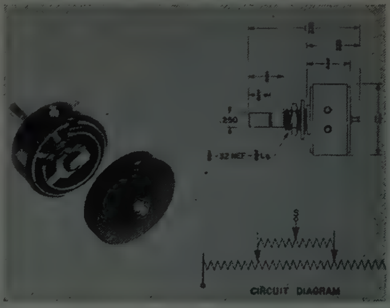
These specifications are possible because of the chopper design which continually compares output voltage against a stable internal reference voltage provided by a Zener diode. The operation is comparable to a "floating battery" and provides excellent isolation from line currents.

Specifically engineered for applications where large numbers of transducers must be powered from a single stable source, the 2–200 will handle 100 bridgetype transducers each with an impedance of 100 ohms and requiring a 5-volt excitation.

Bulletin #101 contains complete information, and is available from the firm.

Vernier Potentiometer

A new concept in high resolution potentiometer design is announced by **Rinco, Inc.**, 7962 S. E. Powell Blvd., Portland 6, Ore. The Type 301-A Rinco-Pot vernier potentiometer provides the desirable combination of high resolution and small size in less than two turns of the adjustment shaft. The Type 301-A consists of an outer case containing the main slide wire and a concentric smaller potentiometer providing vernier action with the vernier resistance paralleling a portion of the main slide wire. The vernier slider is directly attached to the shaft and is connected to the slider terminal through a suitable slip ring. Attached to the vernier frame are two contacts which slide upon the main slide wire approximately 15° apart, therefore, this 15° segment of the main slide wire is effectively spread over the 270° vernier rotation. As the shaft is rotated and the vernier slider completes its rotation, a mechanical stop is



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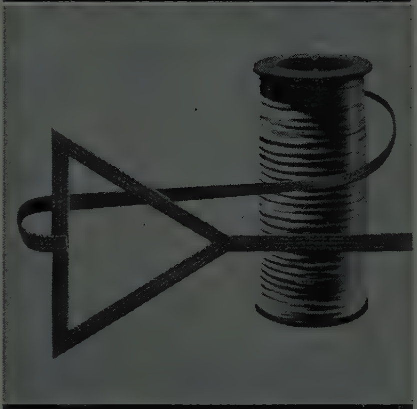

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For lower voltage klystron tubes, PRD type 809 Klystron Power Supply provides flexible, economical performance. Built to the same highest quality standards as type 812, this compact, low cost unit insures optimum performance of a wide variety of klystron oscillators. A clamping circuit in the reflector supply reduces the possibility of double-moding the klystron.

SPECIFICATIONS

OUTPUT		Type 812	Type 809
Beam	Volts, dc Current, ma Ripple, mv rms	200 to 3600 0-125 5 max.	250 to 600 0-65 5 max.
Reflector	Volts, dc Current, μa Ripple, mv rms	0 to —1000 50 max. 1 max.	0 to —900 50 max. 10 max.
Grid	Volts, positive negative Current, ma positive grid Ripple, mv rms	0 to 150 0 to 300 5 max. 3 max.	——
MODULATION		**Type 812**	**Type 809**
Square Wave	Frequency, cps Volts*	500 to 5000 0 to 150 (clamped)	400 to 2000 0 to 90
Pulse	Frequency, cps Volts*	500 to 5000 0 to 150 (clamped)	——
Sawtooth	Frequency, cps Volts*	40 to 120 0 to 200	60, fixed 0 to 125
Sine Wave	Frequency, cps Volts*	60, fixed 0 to 200	——

**volts, peak to peak*

For use with all available klystrons in the low power range and for klystrons at power levels up to 5 watts, the completely new type 812 Universal Klystron Power Supply provides:

- widest application
- closest regulation
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- minimum ripple and noise
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PLUS THESE SPECIAL FEATURES:

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- front panel check calibration of grid and reflector voltages.
- multi-range overload protection for beam current.
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- external triggering of internal pulse generator.

For additional details, contact your local PRD Engineering Representative or write to Technical Information Group, Dept. TIG-1.

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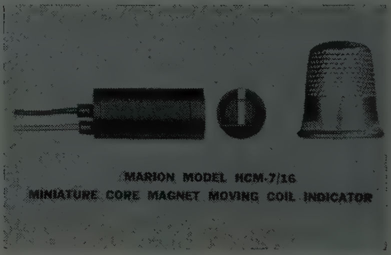
(Continued from page 126A)

engaged which transfers the shaft rotation to the vernier frame causing the spaced contacts to slide upon the main slide wire providing the course adjustment. The shaft rotation may then be reversed and the vernier adjusted to the desired setting, thus, considering the resolution of the main slide wire combined with the vernier action potentiometer, a total resolution equal to, or greater than, a 10 turn 360° helical potentiometer is achieved with 550° of shaft rotation.

Miniature Indicator

A new miniature core magnet moving coil indicator is extremely small in size which permits it to be incorporated within other meters to indicate such information as alarm, position, malfunction, etc.

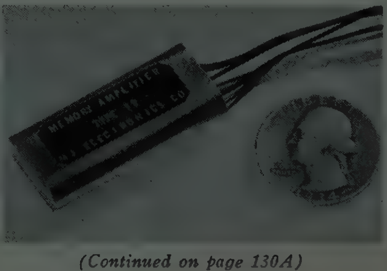


The Model HCM 7/16 is the smallest indicator manufactured by **Marion Electrical Instrument Co.**, Grenier Field, Manchester, N. H. It is a compact rugged hermetically sealed indicator designed to withstand extreme vibration. Dimensions are 7/16 inch in diameter and 15/16 inch long, weight is $\frac{1}{2}$ ounce. The HCM 7/16 is available with either flag or pointer display, and in a wide variety of electrical sensitivities and functions.

Further information is available on request from Marion.

Latching Amplifier and Binary Indicator

The Type 19 Memory Amplifier designed by **MF Electronics Co.**, 122 E. 25th St., New York 10, N. Y., is a latching type amplifier with ability to control power into a load. It takes two input pulses between which power is alternatively applied or removed from the load. It includes four subminiature transistors and a density of 100,000 parts per cubic foot is achieved.



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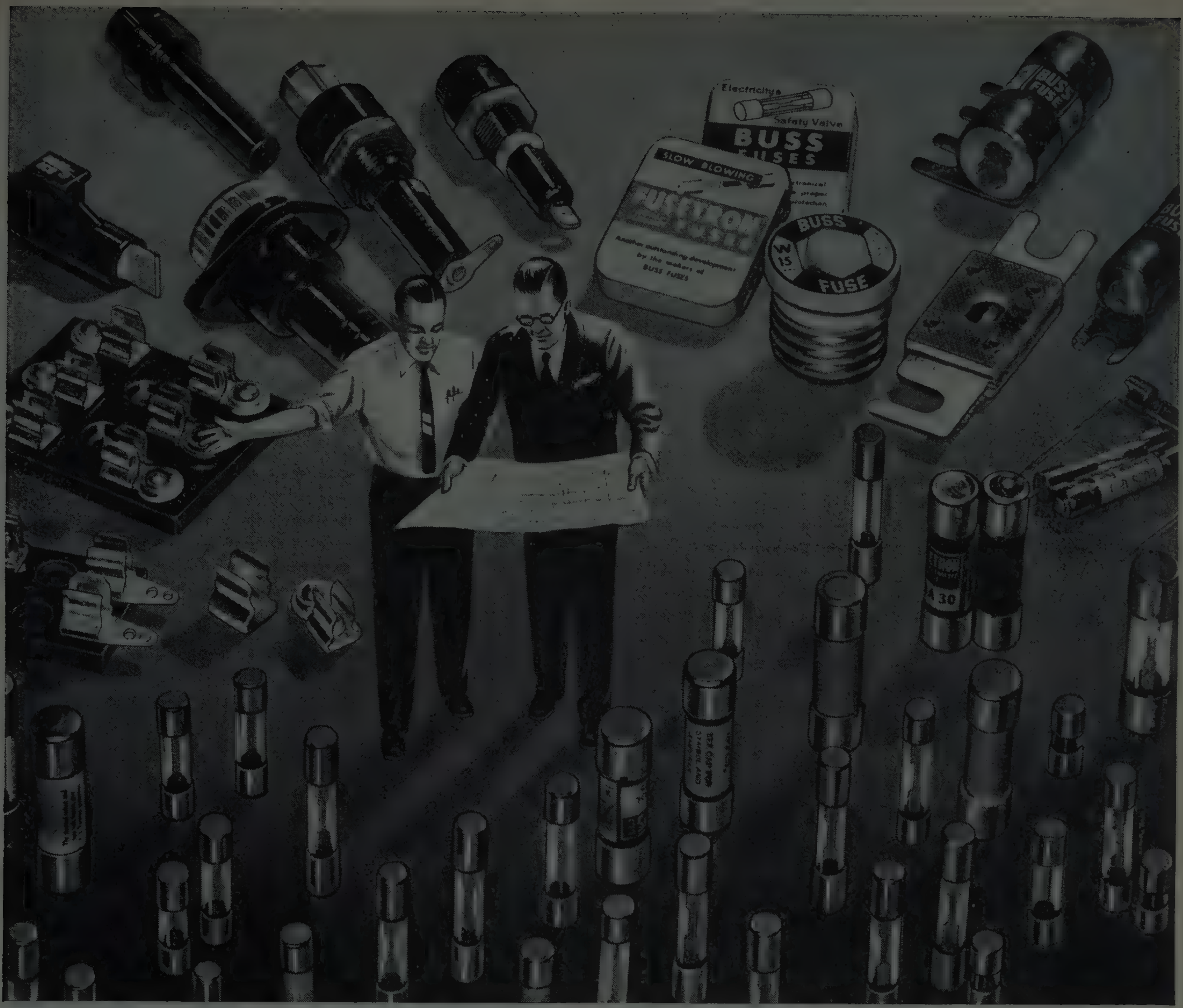
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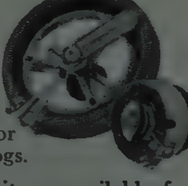

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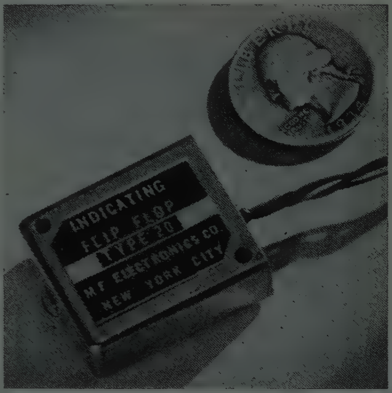
(Continued from page 128A)

The volume is 2/5 cubic inch. It has an extended temperature range from −25 to +50°C. The sensitivity is high, it will "latch-on" with 50 millivolt signal. It will control up to 20 times the load which is required during stand-by condition ("off"). It is ideally suited for working into a power transistor or additional relay to control much larger amounts of power.

The Type 20-Indicating Flip Flop is small, inexpensive to operate at relatively slow speeds but with a unique feature found in no other flip flop of this type.


INDICATING FLIP FLOP TYPE 20
M F ELECTRONICS CO. NEW YORK CITY

It has an indicator lamp mounted on the top of case which glows when the flip flop is in the "1" condition. Since the indicator is an incandescent lamp, with unusual filament characteristics, only 12 volts is needed for supply and a maximum current (at +50°C.) of 10 milliamperes. The Flip Flop is useful for equipment to be used in the field where low weight and low power consumption are the important considerations. No other available binary display unit is said to operate with such low voltage and power.

Motorola Promotes Mendelson

Burt Mendelson has been promoted to the position of Assistant Director of Marketing for the **Communications and Industrial Electronics Div., Motorola, Inc.,** 4501 W. Augusta Blvd., Chicago 51, Ill.

Mendelson had been Manager of the Market and Product Planning Department of the division, which manufactures two-way radio and other industrial communications equipment.

In his new position, Mendelson will continue to supervise new product and market planning activ-

(Continued on page 132A)

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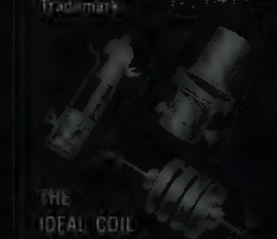

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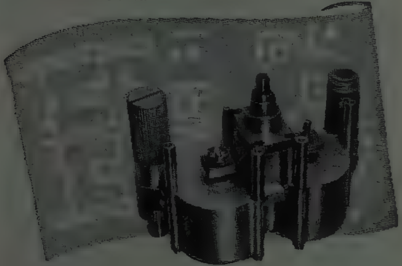

2. Pre-selector-mixer...S band...50 ohm input impedance . . . high Q double-tuned ganged cavities...detector output . . . frequency stable from −55° to +85° C.

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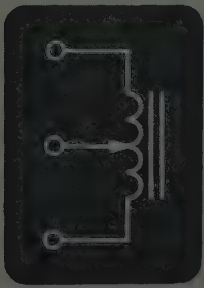

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ELECTRONIC COMPONENTS HANDBOOK, Volume II

JUST PUBLISHED—Gives data on electronic component parts to aid in designing complex equipment for most reliable performance under severe environmental conditions. Components covered are power sources and converters, fuses and circuit breakers, electrical indicating instruments, printed wiring boards, solders and fluxes, choppers, blowers, RF transmission lines, and waveguides. Emphasizes component parts for which tri-service military specifications have been written. *Edited by* KEITH HENNEY *and* CRAIG WALSH, *Technical Writing Service, McGraw-Hill Book Co. Electronic Components Laboratory, Wright Air Development Center. 359 pp., 8½ × 11, 283, illus., $12.50.*

ENGLISH-RUSSIAN RUSSIAN-ENGLISH ELECTRONICS DICTIONARY

JUST PUBLISHED—An indispensable tool for everyone in need of quick, accurate translations of electronics terms in both English and Russian. Translates about 22,000 Russian terms and abbreviations into English, and 25,000 terms from English into Russian. These rigidly accurate and technically sound translations were compiled from all modern sources available in the U.S.A., U.K., and U.S.S.R. *Prepared by the Department of the Army. 944 pp., $8.00.*

ELECTRON-TUBE CIRCUITS

Shows how to analyze and use electron-tube circuits to achieve a broad variety of operations, including work in radar, television, pulse communication, and general electronic control. Thoroughly covers power rectifiers, filters, regulators, amplitude modulation and demodulation, frequency modulation and detection, tuned voltage amplifiers, tuned power amplifiers, and oscillators. Also gives the mathematical formulations for each circuit described. *By* SAMUEL SEELY, *Syracuse University. Second Edition. 529 pp. 641 illus., $10.50.*

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NEWS New Products

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(Continued from page 130A)

ities as well as assist in management of all marketing department functions, according to Irv Koss, Director of Marketing, who made the announcement.

Radio Traffic Control and industrial radio paging are two of the new market areas engaged in by this division of Motorola.

Yttrium-Iron Garnet

The first commercial production of YIG, yttrium-iron garnet, has been announced by **Microwave Chemicals Laboratory, Inc.,** 282 Seventh Ave., N. Y. 1, N. Y. This company also announces that its production also includes other rare earth polycrystalline materials.

YIG, as Microwave Chemicals Laboratory is now producing it, has extremely low loss characteristics, much lower than conventional microwave ferrites in the microwave region. Microwave Chemicals' YIG also has a lower noise factor than ferrites currently available.

This material has a ferrimagnetic resonance line-width of 55 oersteds at 9,000 mc and 30 oersteds at 3,000 mc. Other types of rare earths materials have line-widths varying from 50 oersteds to 2,500 oersteds.

Saturation magnetization is 1,750 gauss. Its exact value, depending on the chemical construction of rare earth garnet employed, varies between 450 and 2,000 gauss.

Applications for YIG include isolators, rotators and parametric amplifiers.

Present commercial production of YIG can be had in either rectangular or cylindrical shapes. The manufacturer states that other garnets can be supplied on special order. Prices on standard YIG and additional information on them can be secured directly from the manufacturer.

(Continued on page 142A)

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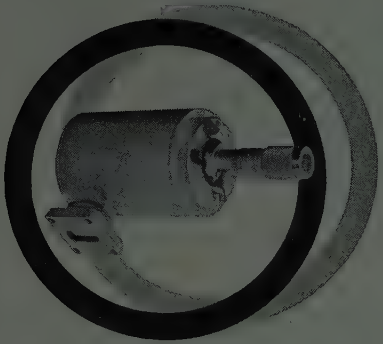

Each instrument covers a wide segment of the total range. Only 11 sizes serve from 2.6 KMC to 90 KMC. Accuracy is so high they may be used as secondary standards. Nitrogen filled and sealed for long life and high Q. Bi-metallic structure provides high degree of thermal compensation. Write for literature.

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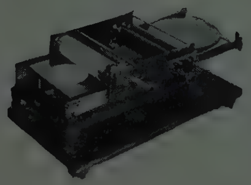

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Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

TRANSISTOR AND MAGNETIC AMPLIFIER CIRCUIT ENGINEERS

For design work on regulated power supplies. Opportunity with rapidly expanding firm. Write Philip Diamond, President, Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.

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Associate Professor for Electrical Engineering Dept. Ph.D. degree preferred. Opening in electronics. Salary commensurate with experience and education. Position available September 1958. Write head, Electrical Engineering Dept., South Dakota School of Mines and Technology, Rapid City, South Dakota.

ASSISTANT OR ASSOCIATE PROFESSORS

M.S. minimum with interest in circuits, computers or servos. Land grant school in the midwest. Salary open. Teach undergraduate and graduate courses through M.S. Write Chairman, E.E. Dept., North Dakota State College, Fargo, North Dakota.

ASSISTANT TO CHIEF ENGINEER

Assistant to Chief Engineer, midwest station. E.E. degree, demonstrated technical ability as well as administrative and organizational experience; salary open. Box 1075.

CIRCUIT DESIGN ENGINEER

Senior circuit development engineer for sweep circuits, power supplies, amplifiers. Located in the heart of the San Francisco Bay area; electronics industry. Moving allowances. Send resume to Menlo Park Engineering, 721 Hamilton Ave., Menlo Park, Calif.

ELECTRICAL ENGINEER

Effective immediately the following position is available in our machine design and development group; degree in electrical engineering; 2 to 3 years experience in design and development of electro-mechanical machines and equipment. Apply Personnel, Assistant Industrial Relations, Haloid Xerox, Inc., Rochester 3, N.Y.

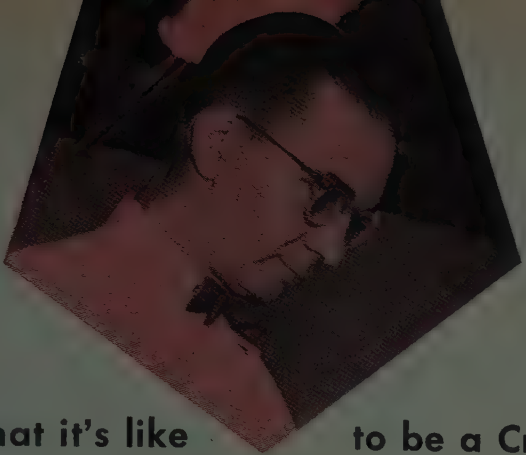
COMPUTER ENGINEERS

Electronics Engineer with 5 to 7 years experience in digital computer pulse circuitry, utilizing solid state components. Knowledge of vacuum tube techniques and machine logic required. Salaries open. Send resume to Underwood Research and Engineering Laboratory, 56 Arbor St., Hartford, Conn.

COMPUTER LOGICAL DESIGNER

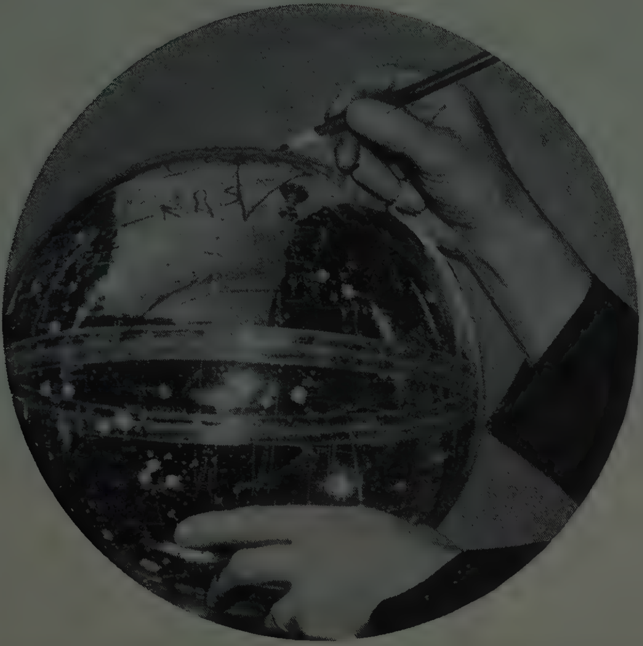
Must have degree in engineering or mathematics plus 5 years experience in digital computers systems studies and logical design. Knowledge of business data-processing systems helpful. Salary open. Send resume to Underwood Research Engining Laboratory, 56 Arbor St., Hartford, Conn.

(Continued on page 136A)



INERTIAL GUIDANCE ENGINEER John V. Prikazsky tells why airborne computer development at IBM Owego, N. Y., offers him the creative engineering career he always wanted.

What it's like to be a Creative Engineer at IBM



"Inertial guidance," explains John Prikazsky, "means aerial navigation without recourse to external reference. As an inertial guidance engineer with IBM, I have the opportunity to work on completely integrated bombing-radar-navigational systems. My work is broad — from lab studies to the analytics involved in system design—everything from shooting the North Star to heat transfer problems. That's why I like it — plus the chance I have to take on as much responsibility as I can handle."

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- Test equipment development
- Radar circuits and systems
- Transistor circuit design

Qualifications

B.S. or M.S. degree in electrical or mechanical engineering, physics, or mathematics, and

Proven ability to assume a high degree of technical responsibility in your sphere of interest.

FOR DETAILS, just write, outlining background and interests, to:

Mr. P. E. Strohm, Dept. 645U
Military Products Division
International Business Machines Corp.
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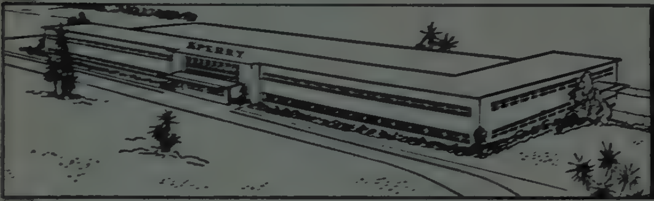

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Research, Development, Product & Product Design Work In Microwave Physics, Advanced Radar And Guided Missile Instrumentation

Sperry's leadership in the development of new concepts in microwave and electronic instrumentation and systems is well known to industry. These developments are important in precision navigation on the sea and in the air; control of many types of missiles; search systems for early-warning radar fences, countermeasures, and many other microwave and electronics projects both military and commercial. This new facility follows in the tradition of Sperry "firsts" which date back to the first gyro compass in 1910 and the first guided missile in 1915.

Qualified personnel joining Sperry here, not only share the opportunities for growth and advancement inherent in a brand-new unit, but also enjoy the security and stability of association with a parent corporation which employs 85,000 men and women in over 70 different plants.

A limited number of select openings exist for engineers qualified to accept unusual professional challenges. Remuneration is commensurate with experience and background. Experience in any of the fields below is required.

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ELECTRONICS — Transistor circuits for military applications; pulse generation and handling techniques; printed circuits.

COMPUTER TECHNIQUES — Digital system logic & equipment synthesis; data handling & conversion.

PRODUCT ENGINEERS — Minimum of 2 years experience in engineering manufacturing coordination; knowledge of development engineering and shop processes; B.S. degree or equivalent in electrical or mechanical engineering.

FERRITES AND SOLID STATE PHYSICS — Isolators, duplexers, amplifiers and other component designs; material studies, broadband, low frequency and high power applications.

MICROWAVE CIRCUITS — Waveguide, coaxial and strip transmission line devices, broadbanding techniques, millimeter techniques.

ANTENNAS — Microwave optics & antenna theory; modern feed, reflector & novel lens designs; search, tracking & communications applications.

MECHANICAL ENGINEERING — Mechanisms, microwave component fabrication techniques, antenna drives and stabilization, equipment packaging.

DESIGNERS — Mechanical or electrical-mechanical experience.

For further information, please contact employment supervisor.

SPERRY

Microwave Electronics Co.

Division of Sperry Rand Corp.

CLEARWATER, FLORIDA

Positions Open

(Continued from page 134A)

COMMUNICATIONS ENGINEER

Opening for graduate engineer with a minimum of 5 years design and systems background in mobile communications. Must be capable of assuming complete technical and administrative control over assigned projects. In reply, please state education, experience, age and salary requirements. All replies in strict confidence. Box 1076.

PHYSICISTS, CHEMISTS, ENGINEERS

Positions now open for research in each of the following fields: gas discharges, electron tube devices including storage tubes, radiation effects on dielectrics, and semiconductors. Send resume to Radiation Research Corp., 1114 First Ave., New York 21, N.Y.

PROJECT ENGINEERS

Immediate openings are available for Project Engineers in microwave communications, instrumentation and telemetry. Openings are also available for young graduate engineers with 1 to 5 years experience. Excellent employee benefits with young growing company. Send resume to Ling Systems Inc., 11949 Vose St., North Hollywood, Calif.

ELECTRONIC ENGINEER

Electronic Engineer to teach lecture and laboratory courses. Up-to-date knowledge of the field required. Working and living conditions excellent; salary and opportunity very attractive. Write to Dean of Engineering, California State Polytechnic College, San Luis Obispo, Calif.

ENGINEER

Engineer to open branch office of Manufacturers Reps. Agency in upper New York State or Boston area, on a partnership basis. Engineering background required, digital background desirable but not essential. Principal has topnotch manufacturers of digital and analog systems and components. Wants to expand. Please send resume to Box 1078.

TEACHERS

Excellent opportunity is available in a new expanding department. Location is at medium sized university in the midwest devoted primarily to undergraduate teaching. Rank and salary commensurate with qualifications. Appointment is available beginning September 1958. Send complete resume to Box 1079.

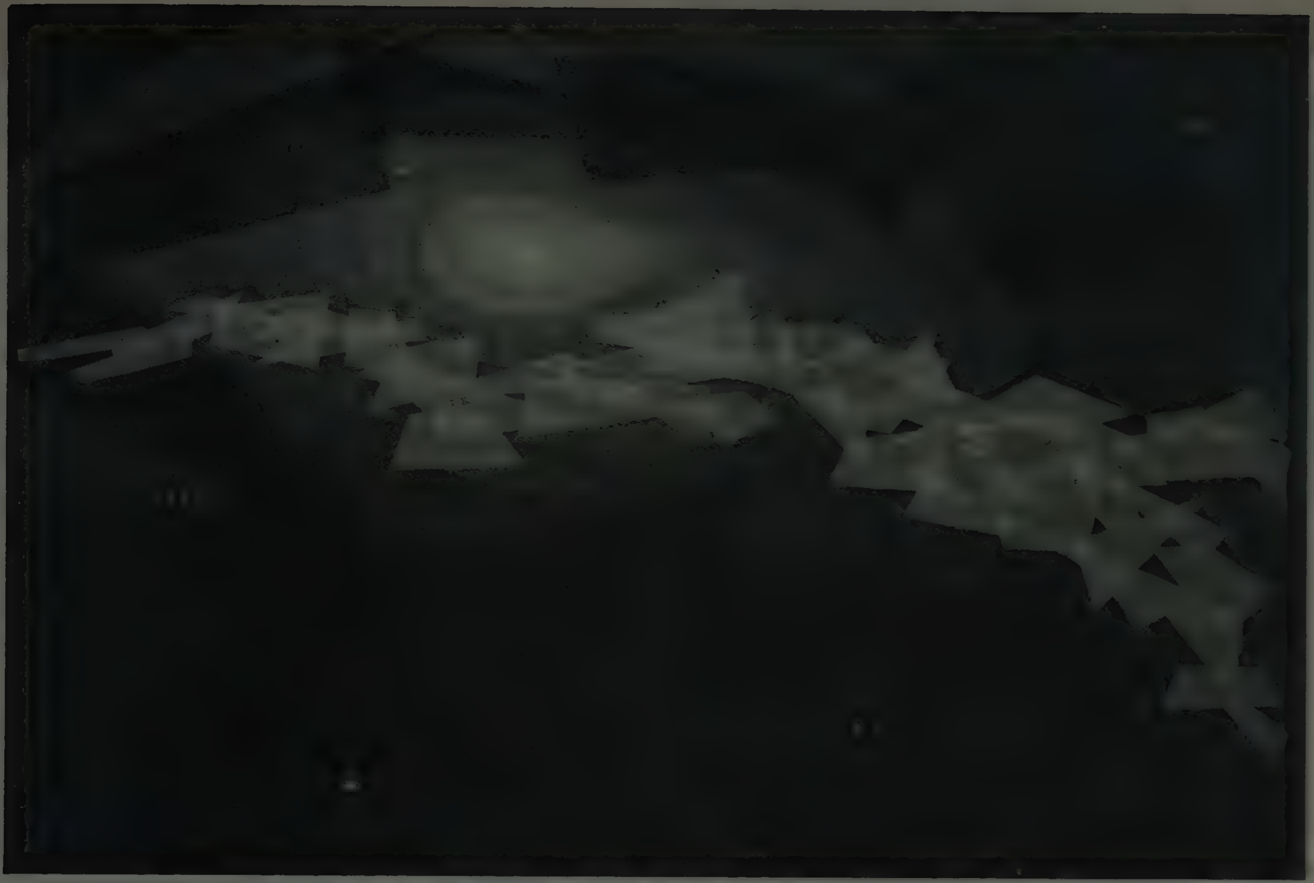
ASSOCIATE PROFESSOR

Associate Professor of Electrical Engineering at medium size state university in the middle west, Ph.D. or D.Sc. and U.S. citizenship required. Fields of specialization in instrumentation, propagation, microwaves and/or antennas desired. Nine months combined teaching and research, salary about $10,000. Summer research employment available. Box 1080.

ELECTRONICS AND RADIO PHYSICISTS, ENGINEERS AND LAB. MECHANICS

The National Bureau of Standards Laboratories in Boulder, Colorado, has several professional, GS-5 to GS-13, and sub-professional, GS-7 to GS-9, openings. The work is in research and development on top national standards and instruments at frequencies to 1000 Mc. Send brief record or request for further information to Section 84.10, National Bureau of Standards Boulder Laboratories, Boulder, Colorado.

(Continued on page 138A)



"CYGNUS," another inspiration by Simpson-Middleman, painters of the meanings of science. "Knowledge of the Universe," say these artist-scientists, "is not a matter of man's sight, but of his imagination's vision. Our eyes show us Cygnus. But creations of our genius, such as the radio-telescope, reveal unexplored, unexplained sources of energy that man may someday master. They lie amidst and even beyond those mysterious, drifting clouds of cosmic matter, lit by the stars they do not obscure." Painting courtesy John Heller Gallery, Inc.

Space-age research at Boeing

Creative scientists find at Boeing a research environment planned to help them reach and stay at the top in their special fields. Pure research along the very frontiers of knowledge is the sole concern of members of the Boeing Scientific Research Laboratories. Problems associated with man's conquest of air and space are high on the agenda, supplemented by investigations in other, equally advanced areas.

Aerodynamicists and mathematicians participate in these programs, along with nuclear physicists, physical chemists, theoretical metallurgists and physicists specializing in electronics and solid state physics. Scientists interested in imaginative, creative research are invited to communicate with Boeing.

Other Boeing openings are available to mathematicians and to engineers of all categories. Assignments are open in the fields of research, design, production and support engineering. For complete details, drop a note now to Mr. Stanley M. Little, Department G-79 Boeing Airplane Company, Seattle 24, Washington.

BOEING

Positions Open

(Continued from page 136A)

ELECTRONIC ENGINEERS

Design and development work in nuclear research for men at all degree levels with experience in the following areas: transistors, tube circuitry, pulse techniques, industrial electronics, instrumentation, reactor control systems, guided missile control systems and telemetering data reduction. Apply University of California Radiation Laboratory, P.O. Box 808, Livermore, California. (U.S. citizenship required.)

COMPUTER ENGINEERS

E/E's, M/E's and Physicists in the areas of: Reliability, Systems Analysis, Magnetic Memory Cores, Circuit Design, Prototype Systems Testing, Specifications, etc. Salaries: $8,000-$16,000. Write to Mr. Aston, Witty-Polon Management Consultants, 25 East 73rd Street, New York 21, N.Y.

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Research Associate to undertake and direct research in Microwave Circuits and Antennas. Duties include post-graduate lectures in Applied Electromagnetic theory and some undergraduate instruction. Inquiry should be sent to Dr. F. Noakes, Head, Department of Electrical Engineering, University of British Columbia, Vancouver 8, B.C., Canada.

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CONSULTANT

Manufacturer in northern New Jersey is interested in obtaining outside consultant having thorough background and experience in design and development of delay lines and pulse transformers. Box 1081.

Positions Wanted

By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

ENGINEER

Desires to travel—or field service. RCA graduate with 3 years radio and TV engineering experience; 1 year computer installation and maintenance. Presently employed in this field. Equipped to travel. Box 1054 W.

PRODUCTION OR SALES ENGINEERING

BSEE, MIT., 1952; MBA Boston University, 1958. 2 years project administration experience Signal Corps Engineering Laboratories. 4 years equipment design experience on instruments and servomechanisms. Desires position with instrument manufacturer in production administration and control or application engineering. Age 27; married. Will relocate. Box 1055 W.

ELECTRONIC ENGINEER

Electronic engineer desires employment in Japan. 8 years experience, including radar, ECM, communications system engineering for Signal Corps, operations research. Interested in position with responsibility, utilizing technical ability. Box 1056 W.

PHYSICIST—ENGINEER

Physicist MS 1958. 1 year experience solid state research laboratory as student engineer. Naval Electronics Technician Class "A" school and 2 years experience in radar maintenance. Age 25, married, 1 child. Presently located in Phila. Will relocate. Available September 1958. Box 1057 W.

MICROWAVE TUBE ENGINEER

BEE, MSc., Eta Kappa Nu, Tau Beta Pi. 18 months Navy Electronic Technician. 7 years experience in design and development of microwave tubes, particularly magnetrons; also some application engineering on the same. Age 31. Desires good research and development job in northeastern quarter of the U.S. Box 1060 W.

(Continued on page 140A)

REPUBLIC AVIATION ANNOUNCES NEW $35 MILLION FOUR-YEAR RESEARCH AND DEVELOPMENT PROGRAM

Includes $14 Million Research Center with 9 Laboratories Being Built to Bridge the Gulf Existing Today Between Aeronautics & Astronautics

Republic Aviation's new Research Center will intensify development of the advanced forms of spacecraft, missiles and aircraft called for in the aeronautical industry's transition to astronautics ■ While special emphasis will be placed upon research in unexplored areas essential to successful manned space vehicles, total projects under study and development cover a broad range including: LUNAR PROBES, MISSILES TO DESTROY ORBITING WEAPONS SYSTEMS, SPACE-TO-SURFACE MISSILES, LONG RANGE AIR-TO-AIR MISSILES, AIR-TO-SURFACE BALLISTIC MISSILES FOR STRATEGIC AND TACTICAL AIRCRAFT, VERTICAL TAKE-OFF FIGHTER-BOMBERS, HIGH MACH INTERCONTINENTAL FIGHTER-BOMBERS AND SUPERSONIC TRANSPORTS.

A NUMBER OF OPPORTUNITIES *for key personnel now exist, to advance and augment our plans in this new program and to staff important positions in the new laboratory operations.*

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To simulate space flight conditions and test missile, satellite and spacecraft systems and components; investigate human engineering problems.

RE-ENTRY SIMULATION & AERODYNAMIC LABORATORY
To study hypersonic shock dynamics, real gas effects, heat transfer phenomena and magnetohydrodynamics.

MATERIALS DEVELOPMENT LABORATORY
Study the effects of high velocity, temperature and space environment on materials for spacecraft, missiles and advanced weapons.

ELECTRONICS DEVELOPMENT LABORATORY
Study and explore all problems connected with highly specialized, complex electronic systems required for advanced forms of spacecraft, rockets and aircraft.

GUIDANCE & CONTROL SYSTEM DEVELOPMENT LABORATORY
To develop and test guidance and control systems for spacecraft and missiles requiring studies in the fields of launch, orbit and re-entry trajectory programming.

ADVANCED FLUID SYSTEMS DEVELOPMENT LABORATORY
To develop and test fluid power systems for spacecraft and missiles capable of operation under extremely high temperature, high pressure conditions.

MANUFACTURING RESEARCH & DEVELOPMENT LABORATORIES
To develop advanced manufacturing processes and techniques for materials used in missiles and spacecraft. Laboratories for each of the following areas: *Non-Metallics, Metallics, and Welding.*

QUALIFIED MEN ARE INVITED TO WRITE DIRECTLY TO:
A. Kartveli, VICE PRESIDENT, RESEARCH & DEVELOPMENT

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Or Send Resume to Dept. PE-18

EQUAL JOB For All Qualified Applicants OPPORTUNITY

RADIO CORPORATION OF AMERICA
Astro-Electronic Products Division
Princeton, New Jersey

Positions Wanted

By Armed Forces Veterans

(Continued from page 138A)

ELECTRONIC ENGINEER

BSEE. (communications option) University of Wisconsin 1955. 3 years experience as electronics material officer U.S. Navy. Released from active duty Sept. 1958. Desires challenging position with diversified engineering and supervisory opportunities in northern Europe or Scandinavia. Box 1064 W.

COMMUNICATION/PUBLICATION ENGINEER

BSEE. Age 34. 10 years experience writing, editing engineering reports, proposals, instruction books, technical-journal articles and patent applications on digital computers, missile guidance, ECM, aerial navigation and solid-state components. Advertising and sales-promotion experience in digital computers. Secret clearance. Supervisory experience. Desires position in New York City or vicinity. Box 1066 W.

ELECTRICAL ENGINEER

BEE. Georgia Institute of Technology 1955. Age 26; single. Completing 2-year tour of duty as officer in U.S. Army Chemical Corps. Available for employment November 1958. Desires employment on Florida east coast. Box 1067 W.

ELECTRONICS ENGINEER

Age 29. 8 years experience navigation, radar, computers. Adept in field work, maintenance and sales. Desires position in sales or unusual challenging task. Location and salary open. Box 1068 W.

ELECTRONIC ENGINEER

Excellent sales record and trained electronic background. Equipped to plan and execute sale program in OEM, industrial or jobber field. Age 36. Now located midwest. Box 1069 W.

SALES ENGINEER

BEE Cornell 1953. Currently graduate student of Electrical Engineering in Tokyo, Japan. Speaks and writes Japanese. American citizen. Single. Experience includes 1 year in the circuits lab of a transistor manufacturer, 1 year as a field engineer, and 2 years in the U.S. Army Signal Corps. Desires part-time technical or technical liaison position in the Tokyo, Japan area. Box 1073 W.

ENGINEER—MBA

BSEE 1950, MBA 1955, University of California. Varied experience in electronic data processing, including logical design of computers, business system design, and computer programming for business applications. Age 30; single. Box 1074 W.

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NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 132A)

Magnetic Voltage Regulators

The Superior Electric Co., Dept. TM, Bristol, Conn., announces the Stabiline type TM (Tubeless Magnetic) Automatic Voltage Regulators to maintain a constant voltage regardless of line or load changes. These units are for unattended or critical process applications where the sudden need for parts replacement can be costly or impossible or where conditions cannot tolerate moving parts. Only a minimum of attention is ever necessary because they have no tubes, transistors or moving parts. The voltage sensing is accomplished by means of a static reference circuit. Stabiline type TM are available in 1 and 5 kva ratings for 115 volt, 60 cps ±5 per cent, single phase duty. For a nominal output of 115 volts (adjustable from 110 to 120 volts) the input range is 95 to 135 volts. The response time is less than ½ second for ordinary line and/or load changes. Even under extreme conditions of line and load changes the maximum response time does not exceed 1.0 second on 1 kva types or 2.0 seconds on 5 kva types. Accuracy is within a 1.0 volt band at a single frequency for line voltage variations and/or load magnitude and power factor changes. For 8-page Bulletin S358TM write to the manufacturer.

Beam Power Tube

Electron Tube Division, Radio Corporation of America, Harrison, N. J., has developed the 7027, a high-perveance beam power tube, for use in push-pull power-amplifier circuits of high-fidelity audio equipment.

RCA ELECTRON TUBE
7027

Featuring high power sensitivity and

(Continued on page 144A)

Flight Controls Design Specialists

You will guide the development of manual and automatic flight controls for high performance VTOL jet aircraft. Openings in the following areas: Automatic Flight Control Systems, Flight Instrumentation, Test Equipment Design, Systems Testing, Manual Flight Control Systems.

Send resume to: Engineering Employment Supervisor, Dept. 0-49,
BELL AIRCRAFT CORPORATION, P.O. Box 1, Buffalo 5, New York.

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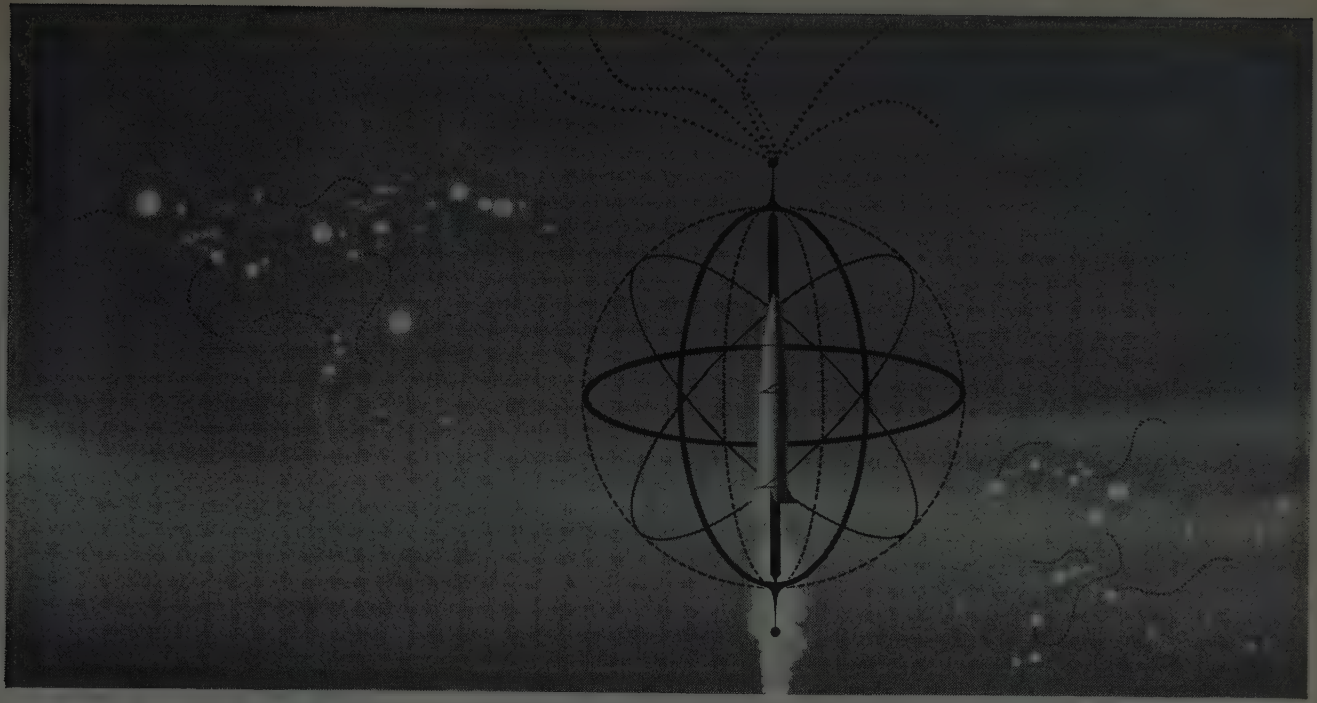
SEND RESUME TO: ARNOLD ADDISON, PERSONNEL DIRECTOR



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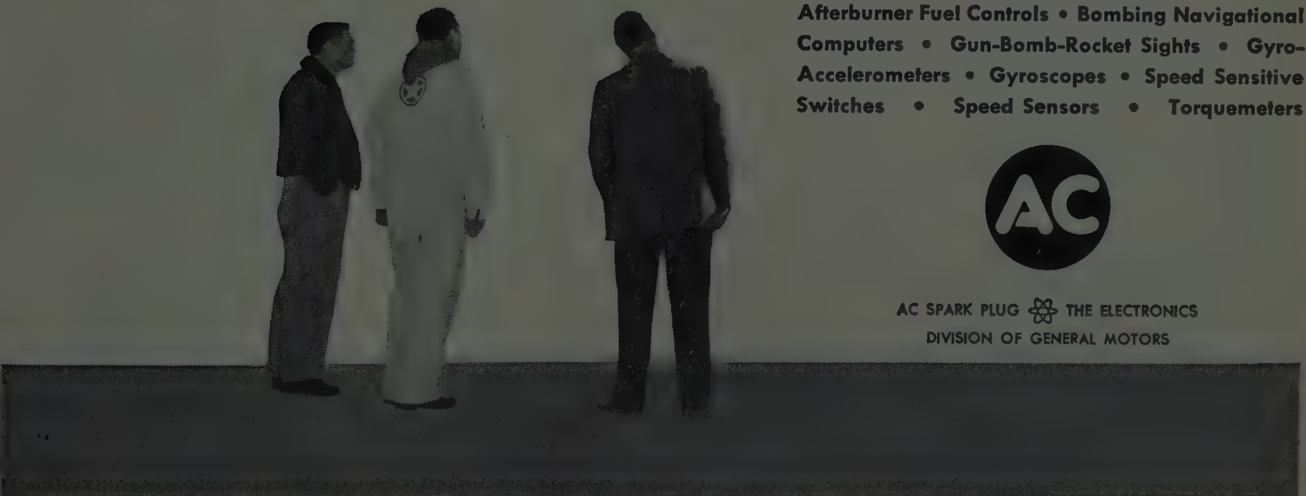
If you are a graduate engineer or physicist with three to ten years technical experience in micro-wave techniques, electronics, the electrical or mechanical fields, or in gyroscope design, you should talk with the people at AC. Just write the Supervisor of Technical Employment: Mr. C. E. Sundeen, Dept. E, 1925 E. Kenilworth, Milwaukee 1, Wisconsin; or Mr. M. Levett, Dept. E, 1300 N. Dort Highway, Flint, Michigan.

Producers of: AChiever Inertial Guidance Systems • Afterburner Fuel Controls • Bombing Navigational Computers • Gun-Bomb-Rocket Sights • Gyro-Accelerometers • Gyroscopes • Speed Sensitive Switches • Speed Sensors • Torquemeters

AC

AC SPARK PLUG THE ELECTRONICS
DIVISION OF GENERAL MOTORS



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If you are qualified for any of the positions below, write, wire or phone today.

ELECTRONIC ENGINEERS, MECHANICAL ENGINEERS, PHYSICISTS

System Analysis, Design and Test
Radar
Navigation
Communications
Missile Guidance
Data Processing and Display

Circuit Design, Development and Packaging
Microwave
Antenna
R-F and I-F
Pulse and Video
Digital and Analog
Transistor
Servos

Technical and Specification Writing
Printed and Etched Circuitry

Write:
Mr. Kel Rowan
Western Military Electronics Center
Motorola, Inc., Dept. C-9
8201 E. McDowell Road
Phoenix, Arizona

Engineering positions also available at Motorola, Inc. in Chicago, Illinois, and Riverside, California.

MOTOROLA, INC.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 142A)

high stability, the 7027 is capable of delivering high power output with low distortion. For example, two 7027's in class AB^1 push-pull service with 450 volts on the plate can deliver a maximum-signal power output of 50 watts with total harmonic distortion of only 1.5 per cent.

Structurally, the 7027 features a plate having the exceptionally high plate-dissipation capability of 25 watts, a control grid with large radiating fins to increase dissipation capabilities, rugged button-stem with short leads having high heat conductivity, and double base-pin connections for both control grid and screen grid to provide for flexibility of circuit arrangement.

Tiny Sampling Switch

The ASCOP Miniplexer, an extremely small rotary sampling switch that promises to contribute significantly to the reduction of weight, size and power requirements in airborne and ground-based electronic systems is announced by **Applied Science Corp. of Princeton,** P.O. Box 44, Princeton, N. J.

This time-division multiplexing device also provides greater service free life, reliability and a wider range of environmental operating conditions than its larger predecessors.

The Miniplexer weighs 2.37 ounces and is ¾ inch long and 1¼ inch in diameter. It has 60 contact pins for 30 channels of make-before-break operation. The new switch replaces one that was five times heavier, three times longer and twice as large in diameter.

This dramatic reduction in size was accomplished through extensive metallurgical research which led to the development of contact pins of exceptional durability and low friction coefficient. The sub-miniaturized assembly results in lower peripheral wiper speeds and longer life.

The switch is expected to prove useful in solving design problems for control and data gathering units in missiles and aircraft. A service free life of 500 hours at 30 RPS is claimed when operated under ambients of +125°C to −55°C and vibration conditions up to 2,000 cps at 25G.

(Continued on page 148A)

ENGINEERS
and
SCIENTISTS
there's genuine opportunity at General Mills

The Mechanical Division of General Mills, Minneapolis, Minnesota, needs senior level staff personnel for creative design and development in the following fields:

Advanced Digital Computer Systems Design

Advanced Digital Computer Circuit Development

Advanced Pulse and Video Circuit Development

Advanced Electromechanical Computer Development

Advanced Inertial Navigational System Development

Optical and Infra-Red Equipment Engineering

Test and Evaluation of Basic Electronic and Electromechanical Components

Aerodynamicists

Telemetry systems engineers

Positions available for *purely technical* and for *technical*-supervisory work—job titles and salary provide *equal* opportunity for advancement in both.

Positions exist in Engineering Department which is engaged in advanced design and development of military weapons and reconnaissance systems, communications, controls, guidance, navigation, and special purpose digital computers. Work is mainly military, with some special commercial instrumentation and control.

If you have at least five years' experience in creative design or development—a good understanding of fundamentals and ability to apply them—learn more about the opportunity and long range security offered at General Mills. You'll like our people, our interesting, non-routine projects—and you'll like Minnesota, land of lakes and pine. In Minnesota everyone takes time to enjoy life.

Write for more facts.

MECHANICAL DIVISION General Mills

Personnel Department P 3
2003 E. Hennepin, Minneapolis 13, Minn.

Helping to get more mileage from America's missile dollar

FIRING missiles costs money. But it's necessary to the development of our nation's security program.

Giving America's missilemen advance assurance of firing performance is the vital, time-saving, money-saving job of missile systems test equipment manufactured by Farnsworth Electronics Company.

This is only one of many important ways this expanding midwestern production center of the ITT system utilizes its extensive facilities for the development, fabrication, and assembly of systems and equipments for missiles and other advanced needs of national defense...for new ways to bring greater efficiency to industry . . . through electronics.

Because of its enormous scope, engineers experienced in product design, packaging, and manufacturing processes find at Farnsworth one of today's most interesting, challenging, and rewarding fields of opportunity. That's why so many outstanding men in their profession have become a part of Farnsworth's 30-year record of progress!

If you'd like to receive a complete picture of Farnsworth activities at Ft. Wayne, Ind., simply write to ITT Technical Placement Office, 67 Broad Street, New York 4.

FARNSWORTH ELECTRONICS COMPANY

A Division of

ITT

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
67 Broad Street • New York

SENIOR RESEARCH POSITIONS

Continuing expansion of our research program has created a need for additional senior members of our research staff. Unusually interesting immediate and long range assignments await those individuals who meet the qualifications set forth below.

Electronic Countermeasures—senior engineer with a minimum of 6 years significant experience in ECM, ECCM, radar and data transmission. Would act as specialist within an operations research team.

Branch Head-Systems Synthesis—to lead a group engaged in designing and evaluating advanced surveillance, weapons and operational control systems.

Missile Guidance—senior engineer with heavy experience in radar and servomechanisms to supervise a group of engineers in guidance and control aspects of a sophisticated missile project.

Instrumentation Specialist—senior engineer with strong experience in modern analogue and digital instrumentation techniques to lead in development of complex data gathering and processing systems.

Systems Analyst—to perform original analytical investigations leading to the development of advanced electronic systems. Strong analytical ability required in information theory, modulation circuit theory, and electronic system synthesis.

Radar Specialist—work is highly varied, including: design and evaluation of experimental radar systems, radar components, airborne radar antenna systems, and technical-operational radar system studies.

Digital Computer Engineer—at least 4 years experience required. Will conduct theoretical and experimental studies relating to digital control systems.

The Organization: Cornell Aeronautical Laboratory is a not-for-profit corporation wholly owned by Cornell University. It is financially self-supporting, and operated for the sole purpose of advancing and enlarging scientific and engineering knowledge. Current research volume is between 13 and 14 million dollars per year, and C.A.L. has completed a total of 100 million dollars of research in its twelve and one-half years of operation. C.A.L. has 1,000 employees.

Desirable Employment Features: VARIETY—the 400 engineers and scientists at C.A.L. are working in 13 technical departments, which last year completed 164 projects, both large and small. INDIVIDUAL RECOGNITION—the high ratio of contracts per engineer, coupled with the Laboratory's practice of using small research teams, allows the recognition of every man's individual contribution. To guarantee this recognition, each man's progress is reviewed every 6 months. SALARY—C.A.L. recognizes its need for above average professionals, and appreciates that such individuals must be compensated accordingly. Annual salary for an Associate Engineer (median of the five non-supervisory categories) can exceed $10,000.

Action to Take: For a prompt and confidential evaluation of your employment prospects at C.A.L., send a brief outline of your education and experience to J. W. Ruch. If you would prefer more information before submitting an application, use the coupon to request the Laboratory's professional employment prospectus "A Community of Science."

CORNELL AERONAUTICAL LABORATORY, INC.
of Cornell University

J. P. Ruch W
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York

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ENGINEERS—SCIENTISTS

Sylvania's Expanding Mountain View Laboratories Offer You...

CREATIVE CHALLENGE TO APPLY YOUR ABILITIES TO CONCEPTION AND DEVELOPMENT OF COMPLEX NEW SYSTEMS AND COMPONENTS ADVANCING THE STATE OF THE ART. **ADVANCEMENT** BASED ON INDIVIDUAL CONTRIBUTION WITH FULL AUTHORITY TO EFFECTIVELY CARRY OUT RESPONSIBILITIES. **CALIFORNIA** SUBURBAN LIVING ON THE SAN FRANCISCO BAY PENINSULA.

SYSTEM STUDIES

Analysis & logical design of digital computer circuits. 7 or more years experience desirable in varied phases of electronic systems analysis with emphasis on computer logic. Advanced degrees desirable.

RECONNAISSANCE SYSTEMS LAB

R&D and Fabrication of reconnaissance systems & equipment.

COMPUTERS & DATA HANDLING

D&D of transistorized circuits & high speed digital computer elements. Openings at all levels for engineers with experience in computer design & transistorized circuits.

ELECTRONIC PACKAGING

Packaging of airborne electronic subminiaturized equipment. 7 or more years experience in electromechanical packaging of electronic equipment desired.

RELIABILITY

Conduct statistical analysis of complex electronic circuits to determine reliability characteristics of the system. Degree in Statistics desirable with 5 or more years experience in some phases of electronics reliability studies.

DEVELOPMENT ENGINEERING

To perform circuit & equipment design and development in the areas of direction finding, data handling, passive detection, receivers, RF circuits and antennas.

MICROWAVE TUBE LABORATORY

R&D and Production of special purpose microwave tubes.

TUBE ENGINEERS

Design, construction & testing of Traveling Wave tubes. Minimum 1 year experience in test & evaluation of TWT's.

TUBE APPLICATION ENGINEERS

Familiarity with tube specifications & test procedures. To work directly with customers to satisfy their requirements. Requires varied background in electronics & microwave tubes.

SR MECHANICAL ENGINEERS

Perform mechanical design & test of tubes, components & tooling. 5 years experience in mechanical design of vacuum tubes, solenoids & microwave plumbing or developing, testing & evaluating special purpose tubes.

TUBE PRODUCTION ENGINEERS

Construction & manufacture of special purpose microwave tubes. 3-5 years experience in vacuum tube production technique.

MICROWAVE ENGINEERS

Plan & perform microwave experiments on ferrites & gaseous electronic phenomena in relation to development of microwave control devices. Experience in microwave transmission & measurement required with experience in high vacuum systems desirable.

MICROWAVE PHYSICS LAB

Research & advanced development: areas of magnetic ferrites & gaseous electron physics.

RESEARCH SCIENTISTS

To perform theoretical analysis & conduct experiments in production of ultra-violet radiation, microwave breakdown in molecular gases & the transmission of electromagnetic waves through ionized shock fronts & plasmas. Background in electromagnetic theory, plasma physics, gas discharges, & atomic physics desirable, as well as knowledge of microwave measurement techniques & vacuum systems. Advanced degrees desirable.

ELECTRONIC DEFENSE LAB

R&D and Fabrication of electronic countermeasures systems & equipment.

SYSTEMS ENGINEERS

With special interest in advanced systems planning for electronic countermeasures systems, systems analysis, experimental & theoretical susceptibility studies, aerodynamics applied to problems by use of analog computer simulation, applied statistics involving decision, theoretic techniques, laboratory test & integration of electronic systems. Academic work beyond bachelor degree or research experience in experimental physics, statistics or electronics desirable.

FIELD ENGINEERS

To work in field on varied domestic & foreign assignments, to install electronic equipment, perform engineering tests, train military personnel & provide engineering assistance to military commanders. BS degree required plus industrial or military electronics experience.

ELECTRONIC ENGINEERS

Research & advanced development in the fields of electronic countermeasures & electronic systems; particular areas of activity are transmitters, receivers, analyzers, direction finders, data handling, RF circuits & antennas. Experience and/or advanced academic training are especially desirable.

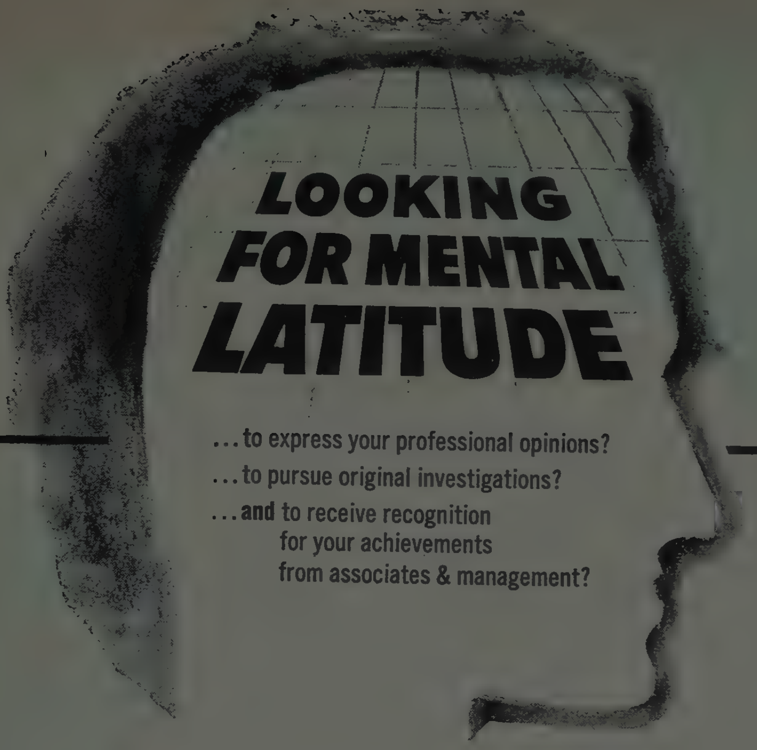
MECHANICAL DESIGN ENGINEERS

Electromechanical design experience, preferably in microwave systems, equipment & packaging. Ability to originate & direct design, to follow through projects. Also engineering experience on high performance precision hydraulic drive & servo control, as in large antenna pedestals. Requires proven creative ability.

Please send your resume to
Mr. J. C. Richards

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
P.O. Box 1296—Mountain View, California



LOOKING FOR MENTAL LATITUDE

...to express your professional opinions?
...to pursue original investigations?
...and to receive recognition
for your achievements
from associates & management?

Engineers

Scientists

Mental freedom is not confined within rigid boundaries at Sylvania's Waltham Laboratories. Scientists and engineers collaborate—but their individual contributions stand out clearly, unobscured by "team" activity.

Men of high professional attainments will find the latitude they seek for original thinking at Sylvania. Taking seemingly impossible projects and creating systems that meet—and surpass—the most difficult requirements is the type of challenge and achievement characteristic of the Waltham Laboratories. Among projects now in progress is the High Speed Data Processing Phase of BMEWS, the USAF's Ballistic Missile Early Warning System.

IF YOU HAVE ABILITY SYLVANIA OFFERS OPPORTUNITY

DATA PROCESSING LABORATORY

(where MOBIDIC, a general purpose digital computer was designed & developed for Sylvania Electronic Systems)

- Sr. Development Engineers
- Sr. Packaging Engineers
- Project Engineers
- Sr. Logical Design Engineers
- Engineers with experience in Radar Data Handling and Display

(Previous digital data processing experience is important for most assignments.)

AVIONICS LABORATORY

- Microwave components design including multi-channel filters incorporating fast-acting microwave switches
- Flush-mounted broad band airborne microwave antennas
- Transistor circuit design & development

MISSILE SYSTEMS LABORATORY

- Advanced development on complex VHF and UHF radar systems
- Systems analysis and synthesis of complex radars, their design and simulation
- Systems simulation, mathematical analysis and guidance system design
- Systems studies in aeroelasticity, flutter, aerodynamics and other aeronautical-mechanical-engineering pursuits

APPLIED RESEARCH LABORATORY

- Research & Systems Application in Counter-Countermeasures, Operations Research, Analysis & Applied Physics

Interview & relocation expenses paid by Sylvania. Inquiries will be answered within 2 weeks. Convenient Saturday interviews arranged.

Please send resume to ERLING MOSTUE
WALTHAM LABORATORIES • Sylvania Electronic Systems
A division of
SYLVANIA
SYLVANIA ELECTRIC PRODUCTS INC.
100-A First Avenue—Waltham 54, Massachusetts

CISLUNAR SPACE
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STRATOSPHERE
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SYLVANIA
IS SEEKING

Physicists, Mathematicians and
Electronic Engineers, MS and PhD

WHO ARE PROBLEM DEFINERS
RATHER THAN PROBLEM SOLVERS

...leading to new Communications Theory and Systems Development (underwater, lower & upper atmosphere, outer space)

These positions are with the Physics Group and the Mathematics Group at Sylvania's new Amherst, New York Engineering Laboratory, which is charged with broad areas of research responsibility for the whole Sylvania Electronic Systems Division.

Scientists and engineers are encouraged to select their own approaches to investigations related to such areas as:

Interplanetary Communications Systems • Composition of Space
Statistical analysis of noise & fading • Optimum signals or communication channels
Efficient applications of redundancy • Physics of the communication channel
Error correction & error detection • Theoretical & applied probability theory
Physical basis of communication • Wave propagation in missile & satellite environments

The work of the Physics and Mathematics Research Groups is mutually supporting and involves frequent and informal consultation between staff members. Men with original minds find the climate stimulating to creative thinking. The responsibilities of the Laboratory are increasing to an extent that will require a substantial increase in the professional staff. There are practically no limits to how far a man can go at the Amherst Laboratory—in professional achievement and personal progress.

An advanced degree is highly desirable for the work outlined. Also depth of experience in such areas as: Experimental & Theoretical Physics, Electronic Systems Development, Information Theory, Probability Theory, Game Theory, Stochastic Processes.

Please send confidential resume to: Dr. R. L. San Soucie
AMHERST ENGINEERING LABORATORY • ELECTRONIC SYSTEMS DIVISION

SYLVANIA
SYLVANIA ELECTRIC PRODUCTS INC.

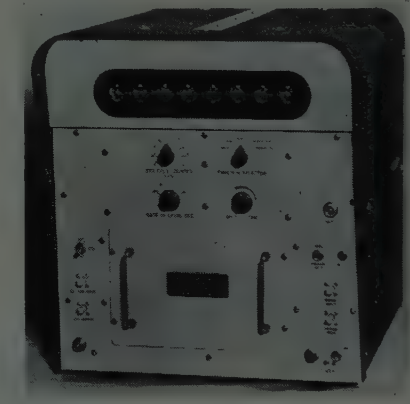
1140 Wehrle Drive
Amherst 21, New York

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 144A)

Electronic Counter

Lavoie Laboratories, Inc., Matawan-Freehold Rd., Morganville, N. J., has a new electronic counter designed to provide the highest reliability, long life potential, and utilization of in-line eight-place Nixie read outs of measured frequency or time intervals. The frequency range is from 10 cps to 10 mc and the range of time intervals is from one microsecond to 100 days.



The unit delivers increased performance and greater flexibility and is designed to meet military requirements. The unit has simplified circuitry, controlled reset, automatic decimal point and temperature stability. The high reliability is assured by a new concept in circuit design perfected by Lavoie, utilizing magnetic beam switching tubes as decade dividers and scalers.

There are additional plug-in units available to increase the flexibility of the unit including frequency converter units, video amplifiers, extended time base units, relay test units and digital recorders.

The counter is physically constructed so that all the components are easily accessible simply by removing the side panel.

For further information write to Lavoie.

Texas Instruments Appoints Owen and Casey

Appointment of Walter H. Owen as General Manufacturing Superintendent and Earl L. Casey as Manager of Division Services of the **Texas Instruments Incorporated, Apparatus Div.,** 6000 Lemmon Avenue, Dallas 9, Texas, has been announced by W. F. Joyce, Vice President in charge of the division.

The Apparatus division designs and manufactures complex electronic and electrochemical apparatus and systems, principally for defense purposes.

Owen joined TI in 1943 as a manufacturing engineer and has held various positions of increasing responsibility. Before his new assignment, he had served as Manager of Manufacturing of TI's precision optics facility in Monrovia, Calif., which recently has been moved to Dallas.

(Continued on page 150A)

FOR 130 ELECTRONIC ENGINEERS

RYAN HAS IMMEDIATE CAREER OPENINGS

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CONTINUOUS WAVE (CW) RADAR

TO WORK ON NEW NAVY AND ARMY CONTRACTS FOR

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MISSILE GUIDANCE SYSTEMS
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ELECTRONIC TUBE PLANT
OF SPERRY
ELECTRONIC TUBE
DIVISION

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ON NEW PROJECTS
In The Microwave Tube Field
for RESEARCH, DEVELOPMENT
and
PRODUCTION ENGINEERS

B.S., M.S., or Ph.D's or equivalent, with previous experience or training on magnetrons, klystrons, and traveling wave tubes, etc.

Here you will find a unique, perfect combination for maximum professional development, expression and recognition...a new division, recently started production, offering exceptional growth potential...yet possessing the stability and "Know How" of Sperry's 50 year history of engineering accomplishments.

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Our plant is located in the University City of Gainesville, Florida, noted for excellent all year round climate, unexcelled fishing, boating and swimming at nearby lake and gulf beaches, uncrowded living conditions with excellent housing available.

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EMPLOYMENT DEPT.

SPERRY
ELECTRONIC TUBE DIVISION
of Sperry Rand Corp.
Gainesville, Florida

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 148A)

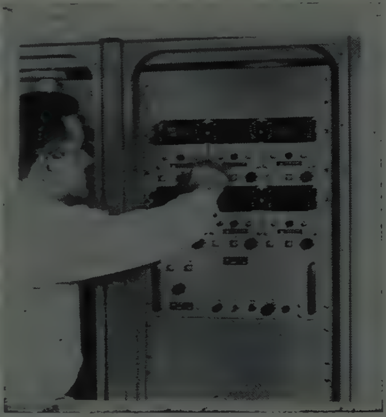
He will report directly to J. S. Dufford, Assistant Vice President in charge of Apparatus manufacturing.

Casey entered the services of Geophysical Service, Inc. in 1937 for work on foreign contracts. GSI was the parent company of Texas Instruments and is now a wholly-owned subsidiary.

Casey was formerly general superintendent of manufacturing for the Apparatus division. In his new assignment, he will be responsible for all plant engineering and office services for the division, reporting directly to Vice President Joyce.

Multi-Channel Tape Monitors

Waterman Products Co., Inc., 2445 Emerald St., Philadelphia 25, Pa., announces the introduction of a series of multi-channel tape monitors. The Model P-106-B Systemat (illustrated), has applications in telemetering, jet engine testing and many other similar jobs.



The Systemat includes six panelscopes mounted in a standard 19 inch rack panel, 14 inches high. A power supply and sweep generator for up to 14 monitors is contained in an associated panelpack. A single panelscope control having two settings permits quick calibration or normal operation. In the calibrate position, 1 by $2\frac{1}{2}$ inch rasters are displayed, indicating that the system is in calibration and operating correctly.

A system of lamps is used to indicate under or over modulation. The model P-106-B is designed to indicate full scale vertically or horizontally with an input of 1 volt rms with a response of dc to 300 kc within 3 db. The panelpack provides sweep frequencies varying from 10 to 10,000 cps.

The overall dimensions of the Systemat are 21 inches high by approximately 14 inches deep (including cables) in a standard 19 inch rack. For further information write to the company.

(Continued on page 155A)

work in the fields of the future at NAA

ELECTRO-MECHANICAL ELECTRONIC ENGINEERS

A BS or advanced degrees in EE, ME, or Physics, may qualify you for a rewarding career at North American Aviation, in one of these fields:

Flight Control Analysis, Reliability Analysis, Flight Simulation, Systems Analysis.

Electrical Systems Analysis and Design, Mission and Traffic Control, Fire Control, Bombing Systems, Electronics Systems Integration, Flight Controls, Ground Support Equipment, Airborne and Electronic Test Equipment.

Applied Research in Radome Development, Antenna Development, Infrared, and Acoustics.

Please write to: Mr. B. J. Stevenson, Engineering Personnel, North American Aviation, Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
NORTH
AMERICAN
AVIATION, INC.

ELECTRONIC ENGINEERS

needed at

MARTIN

New long-term developments at Martin in the field of electronics have created exceptional opportunities for top electronic engineers. At least 5 years experience required. Salaries from $9,000 to $15,000.

Openings in these areas:

- Circuit Design
- Systems
- Inertial Guidance
- Countermeasures
- Digital Computers
- Test Equipment Design

WRITE TO:

William Spangler, Manager
Professional Employment
Department P-9
The Martin Company
Baltimore 3, Md.

MARTIN
BALTIMORE

DIRECTOR, SEMICONDUCTOR RESEARCH & DEVELOPMENT

MICROWAVE ASSOCIATES, INC., INVITES QUALIFIED SEMICONDUCTOR SPECIALISTS TO DISCUSS THE DIRECTION OF AN EXTENSIVE EXPANSION OF OUR EXISTING LONG-TERM PROGRAM IN SILICON DEVICES.

THE MAN WE SEEK WILL BE ASKED TO ORGANIZE THE EXPANSION OF THE EFFORTS OF OUR PRESENT GROUPS ENGAGED IN SILICON METALLURGY AND THE DESIGN OF SUCH DEVICES AS DIFFUSED MESA JUNCTION VARACTORS FOR MICROWAVE PARAMETRIC AMPLIFIERS; SILICON POINT CONTACT MICROWAVE MIXER AND VIDEO DIODES; AND JUNCTION TYPE SILICON RECTIFIERS.

HIS ACADEMIC TRAINING SHOULD BE IN A FIELD CLOSELY ASSOCIATED WITH SEMICONDUCTORS AND ON THE DOCTORATE LEVEL. HE MUST COMBINE KNOWLEDGE OF SOLID STATE PHYSICS, SILICON METALLURGY AND SOME ELECTROMAGNETIC THEORY. IN HIS ACHIEVEMENTS SINCE GRADUATION HE SHOULD HAVE DISPLAYED A NOTEWORTHY BLEND OF CREATIVE AND ADMINISTRATIVE CAPACITIES WHICH HAS GAINED HIM TECHNICAL RECOGNITION IN THE FIELD.

PREVIOUS MICROWAVE EXPERIENCE WHILE DESIRABLE IS NOT VITAL, SINCE OUR PRESENT SEMICONDUCTOR STAFF CONTAINS CAPABLE TALENT IN THIS AREA. THIS EXTREMELY IMPORTANT POST REQUIRES A MATURE LEADER WHO CAN GUIDE, PROGRAM, DEVELOP AND STAFF THE GROWING SEMICONDUCTOR PROGRAM OF A COMPANY WHICH HAS GROWN OVER 50% IN THE PAST YEAR AND IS INTERESTED IN CONTINUED GROWTH.

MICROWAVE ASSOCIATES HAS, SINCE 1950, DEVELOPED A STRONG, RESPECTED AND WELL RECOGNIZED POSITION IN THE SILICON SEMICONDUCTOR FIELD. WE HAVE A DEMONSTRATED RECORD OF CONTINUED AND PROFITABLE GROWTH . . . 300 PRESENT EMPLOYEES . . . AND AN ULTRAMODERN PLANT OF 50,000 SQUARE FEET. SITUATED ON A KNOLL OVERLOOKING BOSTON'S FAMED CIRCUMFERENTIAL HIGHWAY, ROUTE 128, IT IS PART OF THE NEW SCIENTIFIC COMMUNITY SPRINGING UP IN THE AREA.

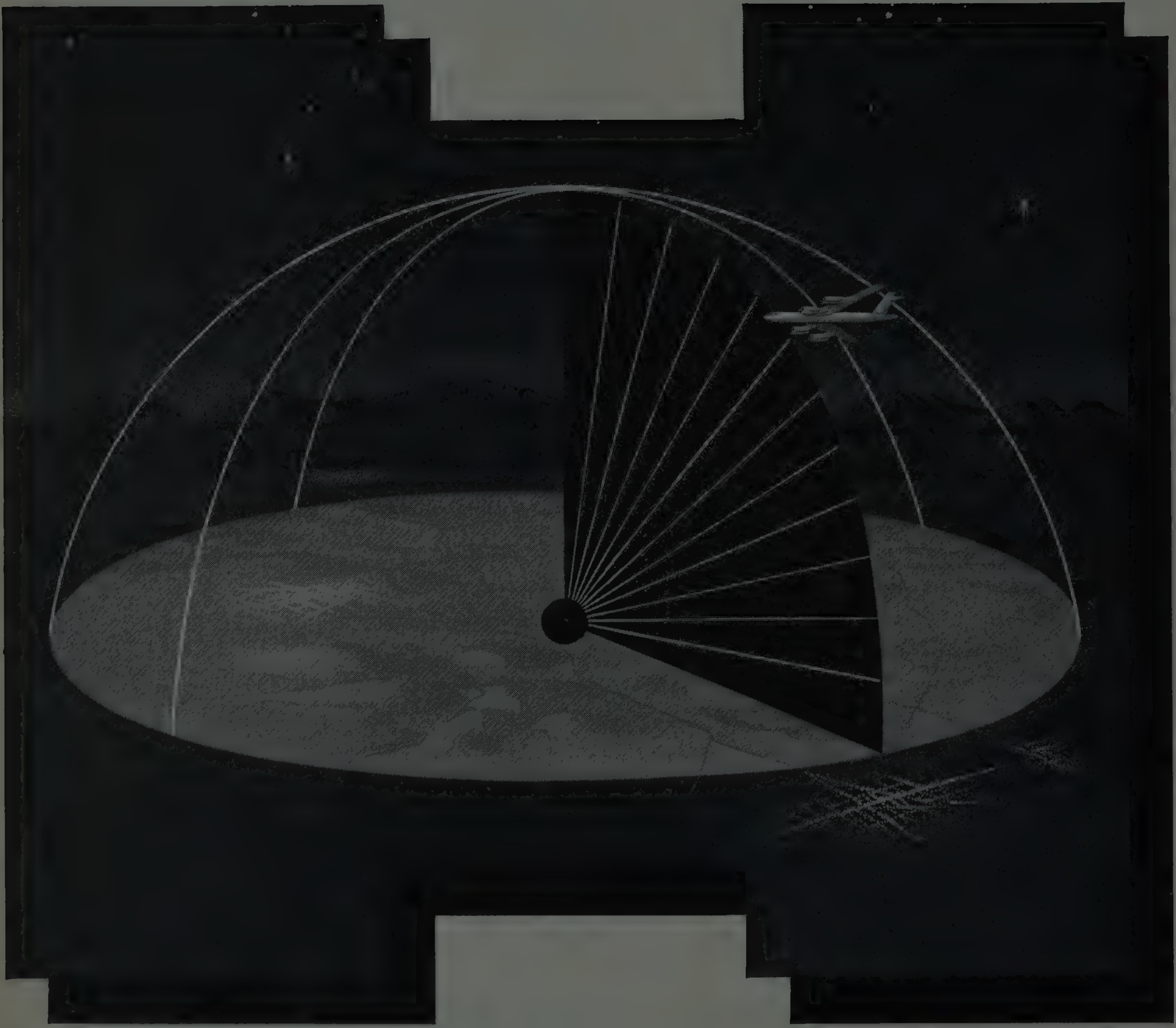
APPROXIMATELY 40% OF OUR EMPLOYEES ARE STOCKHOLDERS. OWNERSHIP ALSO RESTS IN THE HANDS OF AMERICAN BROADCASTING-PARAMOUNT THEATERS INCORPORATED, THE WESTERN UNION TELEGRAPH COMPANY AND THE PUBLIC THROUGH THE SALE OF COMMON STOCK UNDERWRITTEN BY LEHMAN BROTHERS OF NEW YORK.

THE SALARY ARRANGEMENT WILL REFLECT THE CONSIDERABLE IMPORTANCE WE ATTACH TO THIS KEY POSITION AND WILL INCLUDE A LIBERAL STOCK OPTION PLAN. WE WILL DISCLOSE SPECIFIC DETAILS OF OUR OPERATIONS TO QUALIFIED CANDIDATES.

YOU ARE MOST CORDIALLY INVITED TO A CONFIDENTIAL EXPLORATORY DISCUSSION OF YOUR FUTURE WITH US. CONTACT DR. JEROME KORNREICH FOR SUITABLE ARRANGEMENTS.

MICROWAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS ● Telephone: BRowning 2-3000

THE UMBRELLA



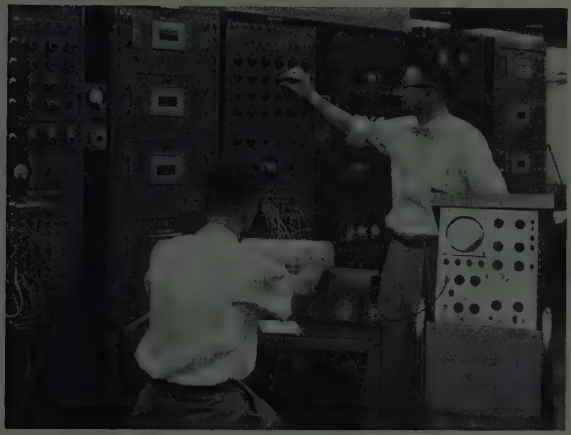
THAT NEVER LEAKS

To achieve umbrella-like radar protection Hughes engineers at Fullerton, California, have developed systems which position radar beams in space by electronic rather than mechanical means. These unique three-dimensional radar systems are digitally programmed to instantaneously detect high-speed enemy aircraft, even at low altitude.

Other defense systems under development at Hughes in Fullerton are Data Processors which monitor the movement of hundreds of aircraft, store the information and assign defense weapons; radars with beams capable of detecting and tracking missiles; and new radar systems for installation on surface and subsurface naval vessels.

Other Hughes activities are delving into similarly advanced areas of electronics. Engineers at Hughes Research & Development Laboratories are probing into the effects of nuclear radiation on electronic equipment, studying advanced microwave theory and applications, and examining communication on a spatial scale. Applying this advanced type of creative engineering to commercial projects is the task of engineers at the Hughes Products activity.

The highly advanced and diversified nature of Hughes projects offers creative engineers and physicists the opportunity to build a rewarding career in a progressive and expanding environment.



Research & Development Engineers use REAC computing equipment as an aid in such complex problems as systems simulation.

Reliability of the advanced Hughes Electronic Armament systems can be insured only with the equally advanced test equipment designed by Hughes El Segundo engineers.

An immediate need now exists for engineers in the following areas:

Electron Tubes
Industrial Systems
Semiconductors
Field Engineering
Computer Engineering
Radar
Communications
Circuit Design
Microwaves
Systems Analysis

Write, briefly outlining your experience, to Mr. Phil N. Scheid, Hughes General Offices, Bldg. 6-H-1, Culver City, California.

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HUGHES

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Culver City, El Segundo,
Fullerton and Los Angeles, California
Tucson, Arizona

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GENERAL ELECTRIC

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 150A)

Forward and Back Current Tester

Trans Electronics, Inc., 7349 Canoga Ave., Canoga Park, Calif., announces the availability of a new test unit for testing germanium or silicon semiconductors. Model FT 1 (Forward Current Tester) has been designed for unskilled operators in quantity testing as well as for the skilled laboratory technician.

Specifications: Output Voltage 0–3 vdc. Line regulations and load regulation each better than 10 mv. Rippled and noise less than 2 mv pp. Six telephone-type lever key switches select desired range in metering both voltage and current. Down positions measure current to 3,000 ma. Up positions measure output voltage on 0–3000 and 0–1000 mv ranges.

Design Features: Combination tube and transistor circuitry is employed with current limited voltage supply. Mirror-back (1 per cent meter) is used together with recorder output, and internal or external load sensing. Unit is complete requiring no accessories; priced at $600.00.

A companion test unit for back current, saturation or reverse testing of germanium or silicon semiconductors is the Model BT 1 (Back Current Tester).

Specifications: The four output voltages (0–100; 0–300; 0–300; 0–1000 volts are each presettable within its range. Rotary selector switch selects any of the four voltages. Line regulation and load regulation better than 0.1 per cent; ripple is less than 0.1 per cent. Metering of both voltage and current is accomplished on six telephone-type lever key switches which select the desired range: (0–1000; 0–300; 0–100; 0–30; 0–10; 0–3). A three-position

(Continued on page 156A)

To the talented engineer and scientist

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APL has responsibility for the *technical direction* of much of the guided missile program of the Navy Bureau of Ordnance. As a result staff members participate in assignments of challenging scope that range from basic research to prototype testing of weapons and weapons systems.

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APL's past accomplishments include: the first ramjet engine, the Aerobee high altitude rocket, the supersonic Terrier, Tartar, and Talos missiles. Presently the Laboratory is engaged in solving complex and advanced problems leading to future weapons and weapons systems vital to the national security. Interested engineers and physicists are invited to address inquiries to:

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(Continued from page 155A)

rotary switch selects the proper multiplier, v (volts), ua (microamperes) and mua (milli-microamperes).

Design Features: Mirror back 1 per cent meter is used in a fully protected electronic metering circuit together with current limited regulated power supplies. Key board metering and recorder output are also employed. Unit is complete requiring no accessories; priced at $575.00.

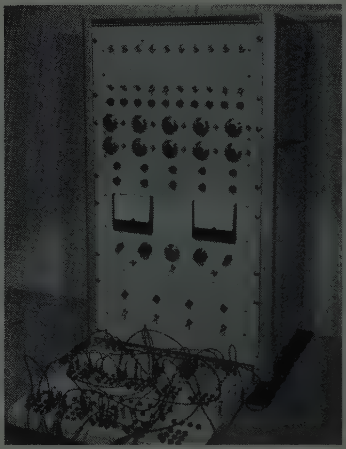
Airborne Crystal Data Sheet

Crystals which will take vibration up to 2000 cps are now in production at **Bliley Electric Co.,** Union Station Building, Erie, Pa., in range 4 kc to 125 mc. These units were especially designed for use in airborne and missile-borne equipment.

Complete design specifications available. Request Bulletin #512 from the company.

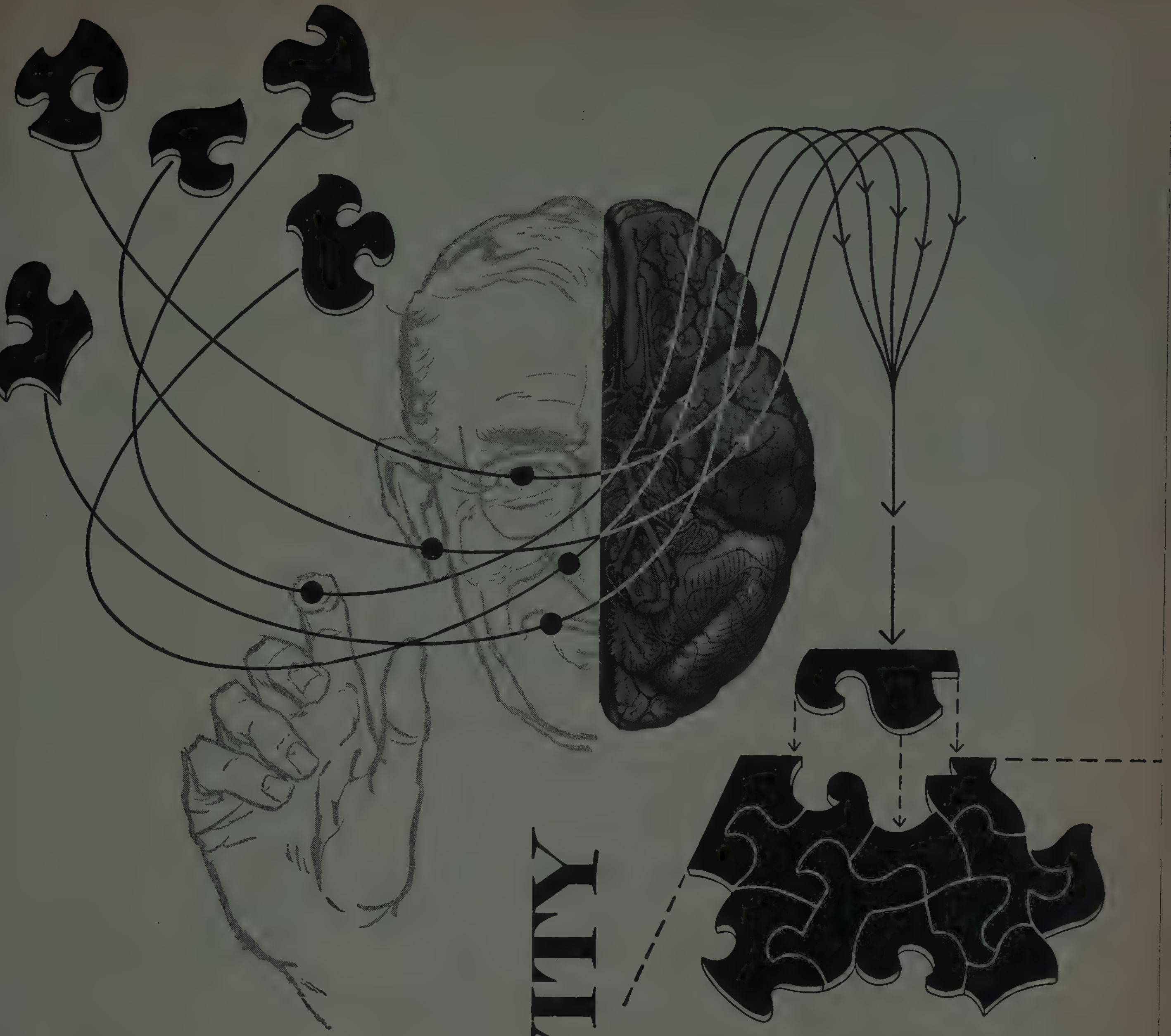
Desk Top Analog Computer

ENSCO Engineering Specialty Co., P.O. Box 19, Sugar House Station, Salt Lake City 5, Utah, has added to its computer line the Model AC-2 desk top analog computer unit which includes components, 10-turn coefficient potentiometers with counting dials, amplifiers, initial condition volt sources, diodes, hold and initial condition provisions, two voltmeters, problem board, patch cords, and self-contained power supply, all mounted in a desk top cabinet with a fan and filter to provide proper air circulation. The problem board is a schematic type using colored jacks and block diagram type markings to facilitate problem setups.



A hold feature which is incorporated in the computer allows any problem to be stopped at any point in order to examine various voltages throughout this setup. Each of the ten operational amplifiers provided is set up such that it may be used

(Continued on page 159A)



Creativity—the continuing progress of civilization and culture is the result of creativity. Science, from the study of the subatomic world to the cosmos, thrives on creativity. The proper environment, availability of equipment, stimulation of other scientists, the challenge to think and the opportunity for interesting problems—these nurture the creative process.

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NEWS New Products

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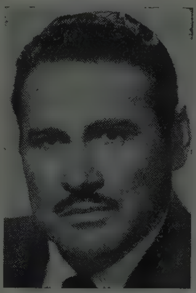
(Continued from page 156A)

as either an adder, an integrator, or sign changer by using proper feedback components. These amplifiers may also be used as differentiators, but such operation is usually not recommended, since noise components within a signal are essentially amplified more than the signal itself through the process of differentiation.

Both voltmeters can read the output of any amplifier by proper selection. Also, voltmeter A can be used as a null voltmeter, or can be switched to read the output voltage of any of the five initial condition sources. Voltmeter B also can be switched to read the outputs of the initial condition sources and when switched into the test positions reads the various power supply voltages that are supplied to the amplifier.

ERA Elects Bodwitch for Pacific Plant

D. D. Grieg, President of **Electronic Research Associates, Inc.,** Cedar Grove, N. J., announces the election of Robert S. Bodwitch as General Manager of the Company's new Pacific Coast facility, ERA Pacific, Inc., located in Santa Monica, Calif.



In his new position, Bodwitch will be responsible for all activities at the new plant including production, sales, and engineering; and the various department heads connected with these individual responsibilities will report directly to him.

Bodwitch is a veteran of many years in the electronics industry and for the past 15 years he has served in both Technical and Administrative capacities. His experience has included both Electronic Systems and Components design for the aircraft and missile industries. He is a graduate of the University of Illinois and has done postgraduate work at the Massachusetts Institute of Technology.

Previously to coming to ERA, he was with Daystrom Pacific, Radioplane Co., and Houston Fearless Corp. He also served with the Military in positions of research and development engineer and was a pilot with Wright Field during World War II.

(Continued on page 162A)

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Our contributions to the system coordination of the Polaris program are another important milestone in Vitro's forward march in the field of guided missile and underwater weapon systems.

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space projects
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Scientists *to work on*

THE FRONTIERS OF SPACE

Lockheed Missile Systems Division, recently honored at the first National Missile Industry Conference as "the organization that contributed most in the past year to the development of the art of missiles and astronautics," holds such important, long-term projects as: the Navy Polaris IRBM, Earth Satellite, Army Kingfisher target missile, and the Air Force X-7 ramjet test vehicle.

To carry out such complex projects, the frontiers of technology in all areas must be expanded. Responsible positions in our research and development laboratories and in our project organizations are available now for high-level engineers and scientists.

If you are experienced in physics, mathematics, chemistry or one of th engineering sciences, your inquiry is invited. Please write Research and Development Staff, Sunnyvale 12, California. (For the convenience of tho living in the East and Midwest, offices are maintained at Suite 745, 405 Lexington Ave., New York 17, and at Suite 300, 840 N. Michigan Ave., Chicago 11.)

FLIGHT IN THREE MEDIUMS

Several things set the Polaris apart from other outer space weapons in the ballistic missile category, for the Polaris program involves a wholly new concept of weaponry:

1. It will be dispatched from beneath the surface of the sea.
2. It will be radically smaller than currently developed land-launched missiles, yet its payload will be as effective and its range the same as other IRBMs.
3. It will be the first operational outer space missile to employ solid fuel as a propellant.
4. It will travel through three mediums in a single flight: water, air, outer space.
5. Its launching base—a submarine—is not fixed but a mobile vehicle.

OUTER SPACE PROGRAM

Very little can be said about the Earth Satellite program at this time except that its success will necessitate advancing the state of the art in all sciences.

The Earth Satellite Project is perhaps the most sophisticated outer space program to reach the "hardware" stage in the U.S. today.

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ENEMY SIMULATOR

The Kingfisher is the nation's fastest target missile, developed for the Air Force and currently being manufactured for the Army to test the accuracy of our newest supersonic weapons.

It is a ramjet target vehicle with Mach 2-plus capabilities. The Kingfisher not only has the speed to match the defensive missiles, but can also simulate a vast array of supersonic enemy missiles and airplanes attacking from great height. It is instrumented to score near misses and even theoretical hits without itself being destroyed.

It is recoverable from flight by parachute to be flown again, permitting weapon system evaluation to be conducted at greatly reduced cost.

Lockheed

MISSILE SYSTEMS DIVISION

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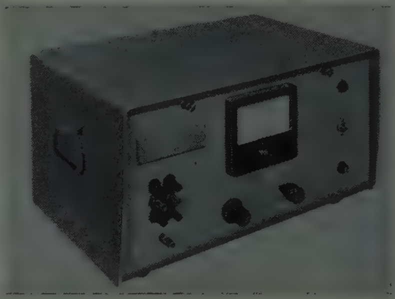
(Continued from page 159A)

Impedance Comparator

The Model 343 Impedance Comparator manufactured by **Inland Electronics Corp.,** 500 Rathbone Ave., Aurora, Ill., features extreme stability accomplished by use of a constant voltage transformer for regulated filaments, an electronically series regulated "B" supply, and voltage regulator tubes.



The 14 tube circuit gives accuracy of 0.05 per cent over wide range of impedances from 10 ohms to 15 megohms without adjustment.

Construction features unique quick access hinged cover for ease in maintenance.

Single scale meter with range switch for 1, 5, 10, and 20 per cent full scale ranges. Price $475.00.

General Purpose Transistors

General Transistor Corp., 91–27 138th Place, Jamaica 35, N. Y., announces the availability of 10 new general purpose transistors, types 2N563 through 2N572. Five of these germanium alloyed junction units are packaged in the Jetec 30 welded case and five are in the military case. They are recommended for applications where tight parameter control and high reliability are desired. All units can be supplied in full compliance with MIL-T-19500A. For complete technical specifications, write to the firm for Brochure G-160.

EHT Rectifier

Claimed to be the first "fully-reliable" E.H.T. rectifier ever produced, the U.60 or OV.4075 has been developed by the **M.O. Valve Co. Ltd.,** England.

Owing to the use of a special cathode

(Continued on page 164A)

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The many areas in which research, development and design groups work include radar, navigation, microwave communications, air traffic control, sonar, automatic test equipment, guided missile electronics, nuclear instrumentation, telecommunications, electro-acoustics, and Hi-fi equipment.

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3. For network design (modern synthesis filters, delay equalizers, loss and phase equalizers) and circuit analysis (transistor amplifiers, transistor pulse forming networks, transistor switching circuitry).

SENIOR PHYSICISTS or EE's

1. For development of solid state circuits to control and instrument nuclear devices.
2. For investigation of fundamental paramagnetic resonances for application to maser-type devices.
3. For development of solid state circuits for application in microwave and RF.

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Engineering experience in electronic packaging and associated problems such as mechanisms, vibration and heat transfer.

SENIOR MATHEMATICIAN

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If you qualify for one of the positions listed above, write immediately to Fred E. Lee, Manager of Technical Personnel.

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For more information please write to: Mr. B. J. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
NORTH AMERICAN AVIATION, INC.

NEWS New Products

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(Continued from page 162A)

of large emissive area, a peak cathode current of 300 ma is obtainable. P.I.V. is 30 kv at 4 ma, and the tube is economical in cathode power. It is therefore particularly useful for flyback E.H.T. circuitry applications, especially in radar equipment undergoing vibration. For inquiries refer to Press W/3819. General Electric Co., Ltd., Magnet House, Kingsway W.C. 2, England.

Meter Shields

Division Perfection Mica Co., 1322 No. Elston Ave., Chicago 22, Ill. has released a new data sheet 138, which illustrates and describes the new line of Netic Co-Netic magnetic shields which fit all meter shapes, aid miniaturization and increase meter reliability, permitting unrestricted use of meters in locations previously impossible for meters to function effectively. Data Sheet available without cost from the firm.

Tape Splicer

A combination butt weld splicer and overlap splicer for any type of magnetic material (mylar or acetate), has been developed by **Prestoseal Manufacturing Corp.,** 37–27 33rd St., Long Island City 1, N.Y.

The design, designated model 300.1 is based upon the basic Prestoseal butt weld concept which requires no adhesives. The unit will handle any width magnetic tape up to 2¾ inches, and has an overlap splice which is flat on the oxide side. It is so designed that it can be made available for any width and can be used to splice video tape and other tapes used in sound or impulse type recording.

The overall dimensions are 9 high × 11¼ wide × 17 inches long, and the unit weighs 17½ pounds. It operates from a 110/120 volts ac source—50/60 cps.

(Continued on page 166A)

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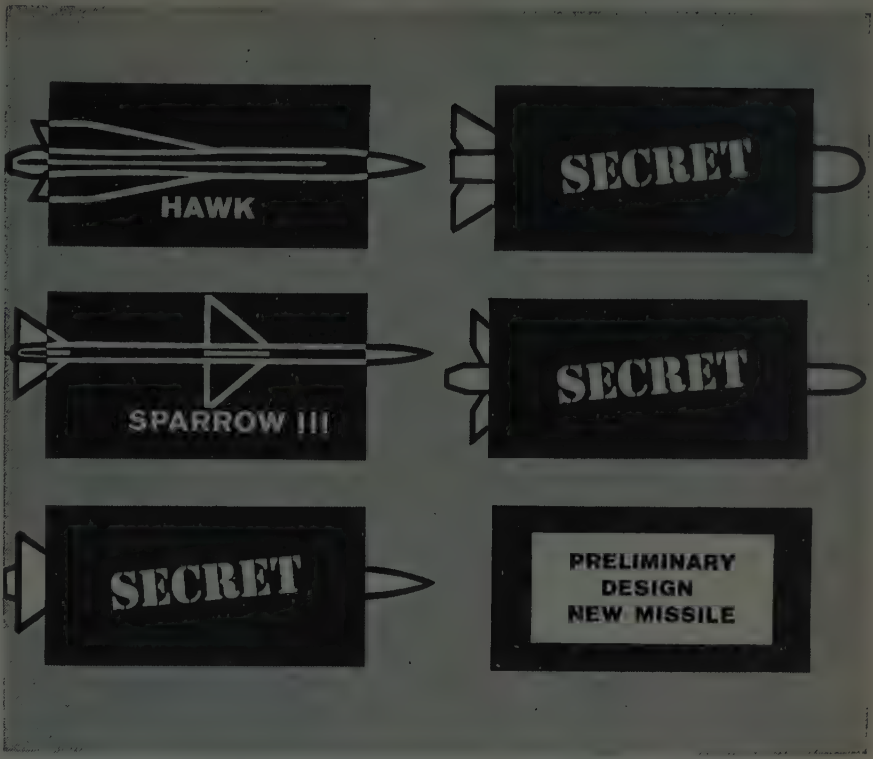

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All resumes will be carefully reviewed by the MANAGERS of our various technical components. If qualified, you will be invited to visit our offices and discuss the work we are doing directly with the manager with whom you would be working. All communications will be entirely confidential. (You need not reveal the name of your present employer.)

Please send your resume to:

Mr. Richard Eddy,
Div. 48-MU

MISSILE & ORDNANCE SYSTEMS DEPARTMENT

GENERAL ELECTRIC

3198 Chestnut Street
Philadelphia 4, Pa.

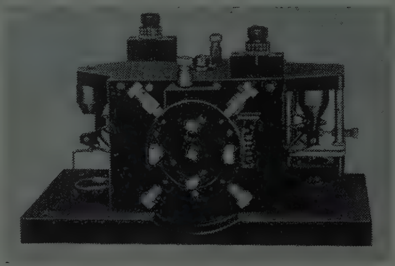
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 164A)

Precision Torque Balance

Reactance and stall torques of small motors used in precision gyroscopes can be accurately measured with the Model 2880 Torque Balance manufactured by **Eder Engineering Co.,** 1568 S. First St., Milwaukee 4, Wis. Heart of the device is a crossed reed flexure pivot with a threshold of 0.05 dyne/cm, providing simplified operation and accuracy within 0.3 per cent+0.05 dyne/cm. The balance has direct-reading ranges of 0.05 to 2 and 2.00 to 1,000 dyne/cm, with a third range of 1,000 to 100,000 dyne/cm requiring a 10X multiplier.



Other features of the instrument include: a capacitor-type position pick-off, two symmetrically opposed permanent magnet solenoids, a weight pan suspended from a double knife edge for calibration, two fluid dampers, and two rotating chucks with radial and rotational centering adjustment.

Electrical circuit components include a preamplifier and amplifier, ring-type phase sensitive demodulator, and potentiometer circuit. Drift of the pick-off null is negligible. The complete device consists of two units which measure 4 feet high×2 feet wide×2 feet deep and 2 feet wide×1½ feet deep, overall size. It is ruggedly constructed and simplified in operation. Details are available in a descriptive folder, "A Precision Torque Balance."

Computer and Data Logging Bulletin

A new brochure is available on digital computer control and data logging. Included in the reference bulletin is a description of the RW-300 Digital Control Computer as well as comprehensive discussions of process control, data logging, pilot plant, and test facility applications for computer control systems.

Published by **The Thompson-Ramo-Wooldridge Products Company.** P.O. Box 45067, Airport Station, Los Angeles 45, Calif., the two-color four-page brochure will be sent free to management and technical personnel.

Detailed specifications are listed for the transistorized RW-300, the first digital computer engineered specifically for automatic on-line control of industrial proc-

(Continued on page 168A)

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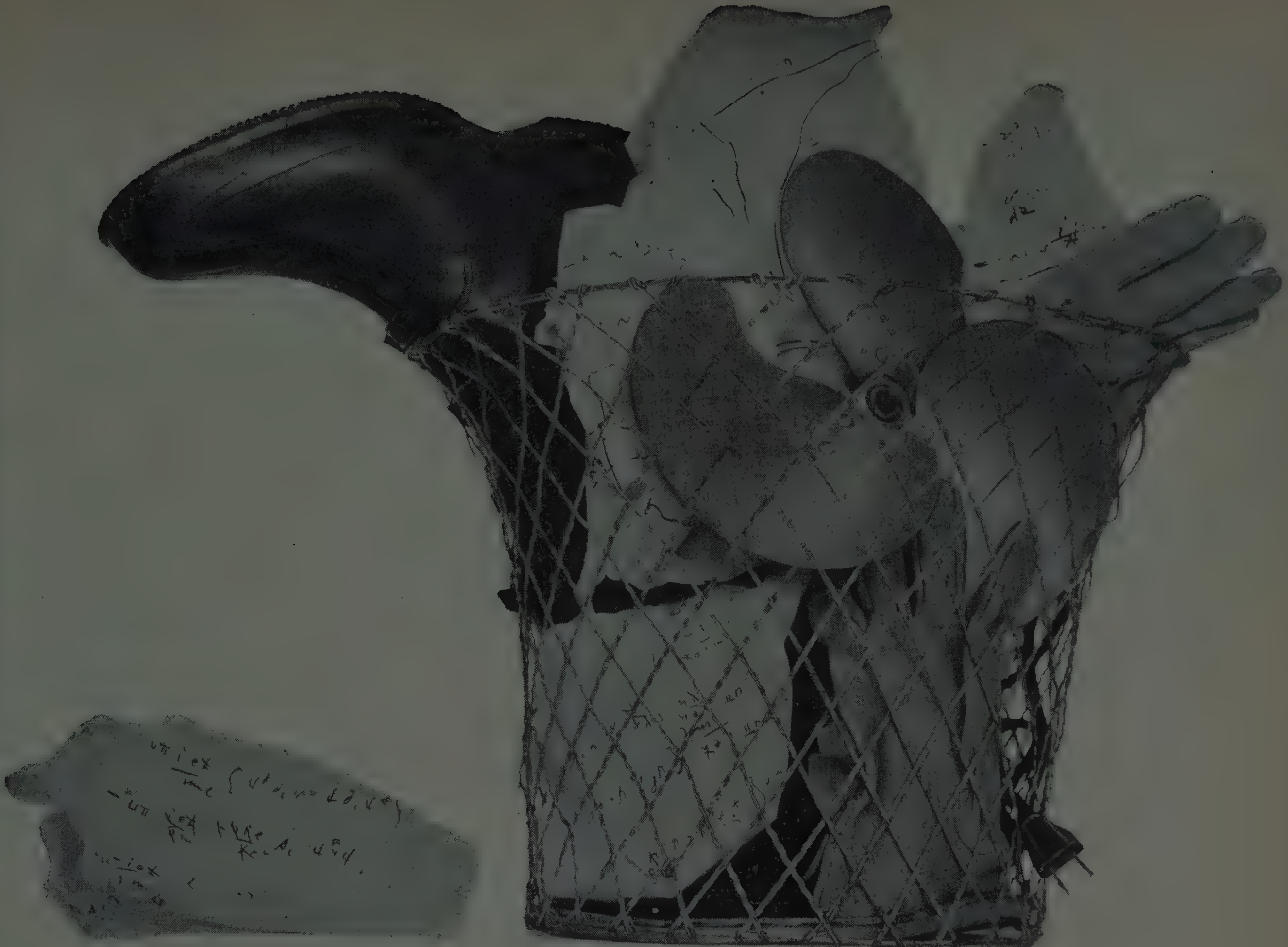
825 San Antonio Rd.
Palo Alto, Calif.



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The climate of learning is at Link-Palo Alto, too. As a participant in the Stanford University Honors Cooperative Program, the dedicated engineer can advance his education by attending regular classes with time and tuition provided by Link.

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Other openings also exist at our main plant in Binghamton, New York.
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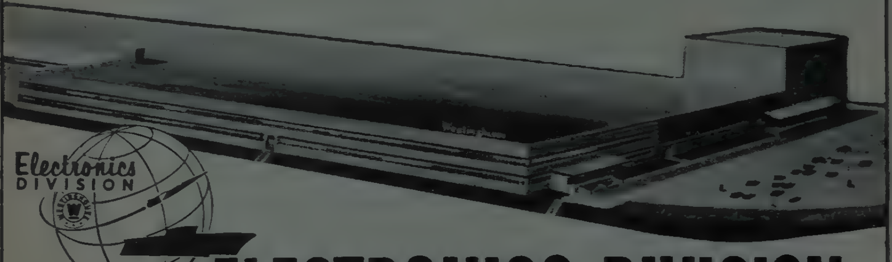

Electronics DIVISION

ELECTRONICS DIVISION

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Pulse Circuitry
Radar Systems
Reliability
Transistor Circuitry

TO APPLY: For a confidential interview, send a resume of your education and experience to Dr. J. A. Medwin, Dept. 808
Westinghouse Electric Corporation,
P. O. Box 746, Baltimore 3, Md.

Westinghouse-BALTIMORE
An Engineer's Company

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 166A)

esses. The computer, which incorporates analog-digital conversion equipment, can handle up to 1,024 analog inputs and up to 128 analog outputs. It can also operate with a wide range of digital input and output equipment, including automatic typewriters, paper tape and punched card readers, paper tape and card punches, and on-off devices.

In addition to control applications, an important use of the RW-300 is in advanced data logging. The brochure explains that requirements exist for data logging in continuous and batch processes where fully automatic control is not being considered at the present time. The brochure also discusses the advantages of the RW-300 over conventional data logging equipment in such applications.

RW-300 control and data logging systems are designed and manufactured by the Ramo-Wooldridge Corporation, Los Angeles. Application and installation engineering, maintenance and marketing of these systems are performed by the The Thompson-Ramo-Wooldridge Products Company, which is owned jointly by Ramo-Wooldridge and Thompson Products, Inc., Cleveland.

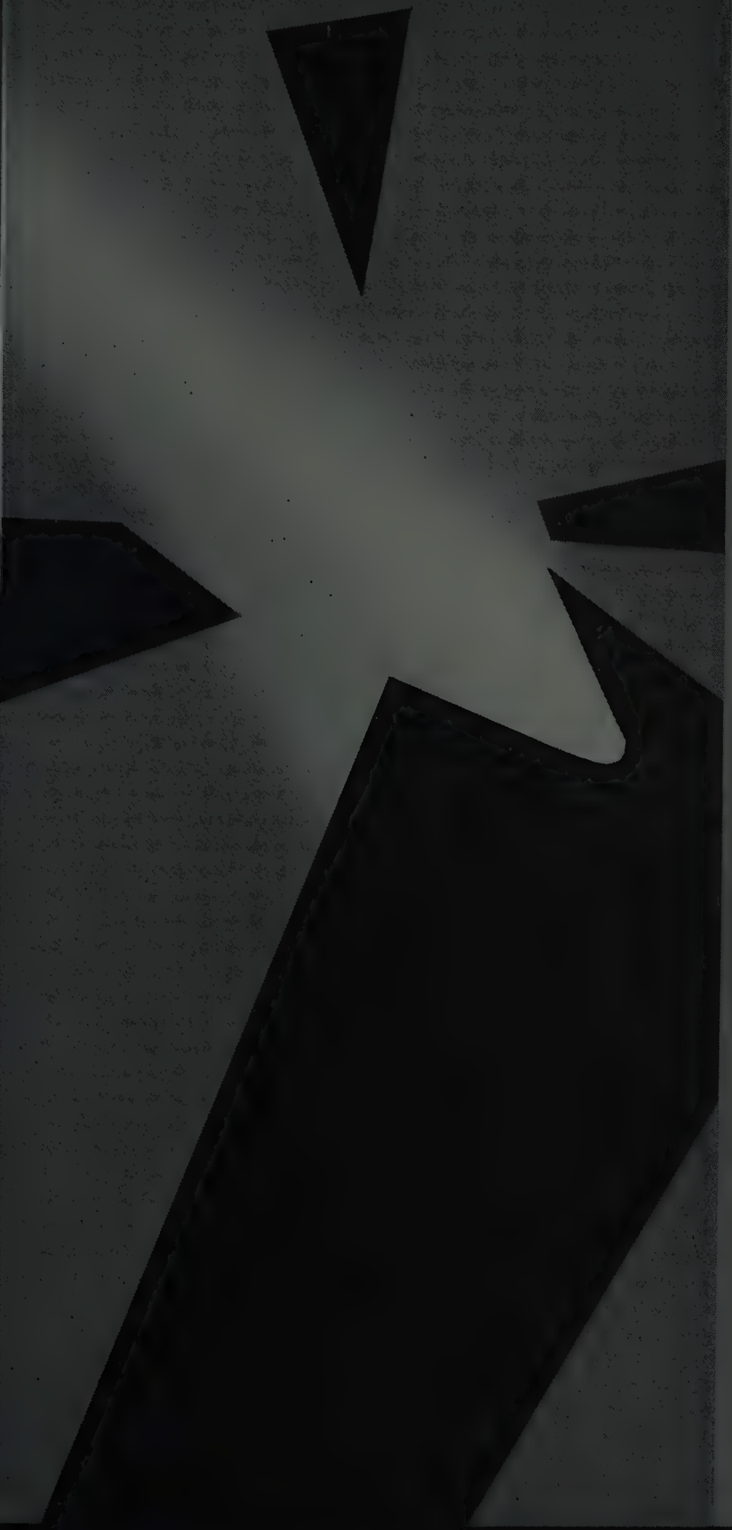
Instantaneous Spectrum Analysis

Two new instantaneous spectrum analyzers, the Sonalyzer Model 100 and the Sonalyzer Model 30, have been designed by **Kay Electric Co.**, 14 Maple Ave., Pine Brook, N.J. Both are designed for such current applications as the study of satellite signals, telemetering, transmission jamming, tube microphonics, transmission of coded frequencies, and Doppler radar.

The Sonalyzers can also perform many of the same functions that earlier vibration analyzers were used for including acoustics studies, shock and vibration analysis for equipment inspection, phonetic studies, speech education for the deaf, etc. Both instruments display the Fourier frequency components of sonic and ultra-sonic disturbances of short duration.

The Sonalyzer Model 100 analyzes 2500 cps bandwidths in the 50–7,500 cps range in three bands. With an external oscillator, it will cover up to 50 kc in the same 2500 cps bandwidths. The spectrum under analysis is simultaneously applied

(Continued on page 170A)



THE

PLASMA JET—

a case of research and advanced development

Development of a re-entry simulation facility for the Air Force *Titan* ICBM nose cone required a method for heating air to extremely high temperatures. A special type of electrical discharge, sometimes called a "plasma jet," was considered. Both *fundamental* research—to obtain a quantitative understanding of the arc properties and mechanism—and *applied* research in actual aerodynamic and materials testing were needed. Advanced development—the actual design and construction of improved test facilities—was also an inherent part of the problem.

Theoretical and experimental physicists, aerodynamicists and physical chemists began a simultaneous attack on the fundamental processes. At the same time, and in close association with the others, instrumentation and mechanical engineers began to build and use a series of continually improved facilities for re-entry testing. Those inclined toward either fundamental or applied research in their particular specialty were able to maintain their integrity and their own research approach. At the same time they were able to benefit from the close working association with one another.

The results were especially fruitful. The plasma jet has proven an excellent tool for re-entry studies. Investigations of important applications in high-temperature chemistry, space propulsion and refractories are following as an added bonus.

Research and Advanced Development is more than a descriptive title at Avco. It is a concept that promotes creativity.

For information on unusual career opportunities for exceptionally qualified scientists and engineers, write to: Dr. R. W. Johnston,
Scientific and Technical Relations,
Avco Research and Advanced Development Div.,
201 Lowell Street, Wilmington, Mass.

AVCO

Research & Advanced Development

DATA PROCESSING
MICROWAVE
INFRARED
CLOSED LOOP TV

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acf industries incorporated
4

Positions are open at our Paramus, N. J. and Alexandria, Va. research & development laboratories. Both are ideally located in highly desirable residential communities, convenient to world-famous cultural, entertainment and shopping centers.

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—ANALYSIS & SYNTHESIS
—RESEARCH & LOGICAL DESIGN
—DIGITAL COMPUTER DESIGN
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Thoroughly experienced to take full responsibility of project groups.
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(Continued from page 168A)

to 100 25-cps-spaced magnetostrictionfilters, each 32 cps wide. The energy at the output of each filter is sampled in sequence by a high-speed capacitance commutator. Out-of-phase summation of these scanned filter outputs achieves noise cancellation and frequency resolution high enough to distinguish signals 60 cps apart.

The Sonalyzer Model 100 is sensitive enough to detect an input as low as 0.5 mv; its linearity is such that the voltage-in to voltage-out ratio is linear to within ±1.5 db.

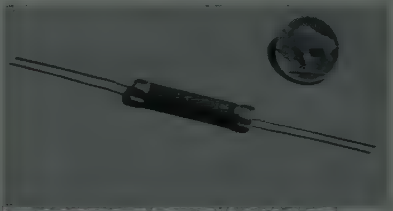
The Model 30 relates a single amplitude to frequency to make an instantaneous graphic display of complex audio waveforms. It is a heterodyne-type analyzer which separates 4-kc-wide bandwidths up to 20 kc (higher on special order) into 29 equal frequency bands. A 30th channel is provided for reference.

The energy in each band is the ordinate while frequency is the abscissa of the scan. The signal to be analyzed is amplified and modulated by a high frequency local oscillator. The modulated signal is amplified and applied to 29 crystal filters each with a 135-cps bandwidth.

An electronic commutating circuit scans the outputs of these filters in rapid sequence and applies the energy to the indicating electrode. The scan of the indicator is synchronized in a 1:1 ratio with the electronic commutator.

Oxide Film Resistor

Special feature in the WESCON exhibit of **P. R. Mallory & Co., Inc.,** 3029 E. Washington St., Indianapolis 6, Ind. was a live demonstration of a new 500°C oxide film resistor. For the demonstration, the resistor was connected in a circuit and housed in an oven at 500°C.



Other Mallory high temperature components shown for the first time to WESCON visotors were a gold-plated $\frac{1}{4}$ inch potentiometer (up to 250°C); type XTM Tantalum capacitor (175°C); type M2 miniature Tantalum capacitor (150°C) Milli-Switch, a precision electrical switch (up to 150°C); and the type TAS subminiature, solid electrolyte Tantalum capacitor (125°C.)

Mallory also displayed a new type CH-Chopper, a transistorized power supply, an operating timer, and a transistorized static inverter.

(Continued on page 173A)

Man-Machine Relationships: A New Field for Engineers and Scientists

A new field for Operations Research Specialists, Engineers, Computer Programmers and Behavioral Scientists has arisen from SDC's work on relationships of men and machine systems.

It involves two major projects: 1 *creating and conducting large-scale training programs in present and planned air defense systems; and* 2 *operational computer programming for SAGE.*

Attaining the most effective interaction between men and machines in these programs is of prime importance. It requires intensive effort in an unusual combination of technical and scientific areas. As such, it is a new field of endeavor.

Both programs also have these elements in common: • they are constantly changing in problems • they are long-range in nature • they are essential to the welfare of the United States. The close interrelationship of these programs, the widely diversified specialists engaged in them, and the dominating influence of man-machine relationships make SDC's work unique. Operations Research Specialists, Engineers, Computer Programmers, Behavioral Scientists — all find their assignments reflect the unique qualities of this new field.

The growing complexity of SDC's work has created a number of positions in these fields. Inquiries are invited. Address: R. W. Frost, 2418 Colorado Avenue, Santa Monica, California, or phone collect at EXbrook 3-9411 in Santa Monica.

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Those interested are invited to write to the
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638 Commercial Trust Building Phila. 2, Pa.

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(Continued from page 170A)

Decade Counter Bulletin

Technical Product Information Bulletin No. 826 just released by **Burroughs Corp.**, Electronic Tube Div., Plainfield, N.J. contains specifications and descriptive information on their line of Decade Counters containing Beam Switching Tubes and Nixie® Indicators.

Four models of the Decade Counters designated as types DC-101, DC-102, DC-103 and DC-105 are described in detail in this 6-page brochure. Photographs of these units are supplemented by schematic drawings and specifications.

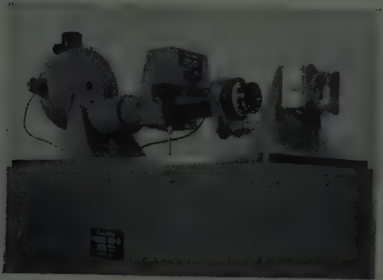
Schematic drawings of typical associated circuits such as driver circuits, a one microsecond reset circuit, a one decade preset circuit, a photocell driver circuit and a remote Nixie readout circuit are also provided. These circuits will assist the design engineer in incorporating the counters in military and commercial systems and test equipment.

Further information can be obtained by contacting Burroughs.

Continuous-Writing Streak Camera

A research tool for the photo-instrumentation study of self-luminous transient events, the new Model 194 Continuous-Writing Streak Camera, produced by **Beckman & Whitley, Inc.,** 972 San Carlos Ave., San Carlos, Calif., produces a documentation which is a plot of space in one direction versus time in a 90° direction.

Primary applications will be in the study of explosions, shock-tube manifestation, and flash-tube and spark-discharge phenomena. Because of the continuous writing feature, the requirements of synchronizing the camera and the event is eliminated, greatly simplifying use.



The new instrument mounts on its own base and control housing. Standard 35-mm film, arranged for daylight loading and unloading, is used. The image is swept onto this film by a rotating triangular mirror driven by a high-speed turbine. Several types of these drives are available—the fastest one, ranging from 200 to 5500 revolutions per second, is driven by helium gas.

(Continued on page 174A)

The first in a series of professionally informative messages on the Ballistic Missile Early Warning System.

RCA MOORESTOWN
AND BMEWS

At its Moorestown Engineering Plant, RCA has centered the responsibility for direction of the BMEWS Project. As Weapon System Manager, RCA has the task of "turnkey" delivery of a fully integrated system for early detection of missile attack on this continent. BMEWS involves establishment of a discriminating and alert line for detection of aerial objects, coordinated with an intelligence center for interpretation and initiation of counter-weapon action.

There are unique technical problems in high radar power; long range; scanning and tracking techniques; interference from aurora and space objects and discrimination between such objects and missiles; advanced computer, multifunction data processing and display techniques. The BMEWS program also requires complicated coordinative assignments in supervising the large segment of the electronics industry cooperating in this effort. The complete scope and defense significance of BMEWS assignments are creating stimulating challenges in systems, projects, and development engineering.

Engineers and scientists interested in contributing to this program—and to other vital national defense projects—at the technical or management level are invited to address inquiries to Mr. W. J. Henry, Dept. V-17J.

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Fundamental research in new mathematical routine for digital computers

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ELECTRONIC ENGINEER $12,500
Good bkgd in panoramic receivers & counter measure systems, Connecticut

MICRO WAVE $12,000
Design & development of microwave systems, antennas and plumbing

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Packaging of electronic circuits, familiar with military specs

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SONAR ENGINEER to $12,000
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ELECTRONIC ENGINEER to $11,000
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RELIABILITY ENGINEER $9600
Select components and specify electrical devices; need 1 man with EE and 1 with ME. New Engl.

ELECTRONIC ENGINEER $9000
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Harry L. Brisk—Member IRE

ACCREDITED PERSONNEL SERVICE
12 So. 12th St., Philadelphia 7, Pa.

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page [illegible])

This arrangement produces a maximum writing rate of approximately 8 millimeters per microsecond; a total writing time at top speed of 58 microseconds; and a maximum time resolution, using a 0.004-inch wide slit image and film having a resolution of 75 lines per millimeter, of 2.5×10^{-8}.

The finished useful record is approximately 18.5 inches long. Its length is identified by three fiducial marks automatically placed in the margin of the film which locate the center of the record and the limit of useful data which is 114 degrees either direction.

The Model 194 has control equipment which includes an events-per-unit time meter for accurate measurement of the mirror speed to provide a determination of writing rate; mirror-speed adjustments; and controls for the capping shutter and the explosive-actuated blast shutter, used to prevent rewriting in the case of long duration events.

Tantalum Slug Capacitors

Tan-O-Mite (R) brand (Series TS) capacitors constitute the third type of tantalum electrolytic capacitor to be announced by **Ohmite Manufacturing Co., 3693 Howard St., Skokie, Ill.** This type employs a porous slug of sintered tantalum for the anode in contrast to Ohmite's tantalum foil (Series TF) and tantalum wire (Series TW) types. Series TS slug capacitors feature the extraordinary shelf and operating life, stability and wide operating temperature range which derive from the inertness of tantalum metal and the stability of its oxide film.

In comparison to other electrolytics, Series TS units offer closer capacitance tolerance combined with unusually low leakage current and equivalent series resistance as well as high capacity for small size. Supplied in silver cases, their capacitance range is 1.75 to 50 μf—working voltages to 125 are available. They are polar units intended for dc applications, but will function where some ac ripple may be superimposed.

For complete information (Bulletin 139), write to Ohmite.

(Continued on page [illegible])

COMPUTER ENGINEERS

Several Computer Engineers are required to service a large scale, parallel mode, binary digital computer with buffered magnetic tape input-output. Applicants must have above average understanding of electronic circuits and a Bachelor's degree in Electrical Engineering or equivalent practice experience. This is a permanent position with a leading research center and offers a challenging opportunity to qualified personnel. Receive an excellent salary and outstanding employee benefits, and enjoy stimulating staff associations.

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ARMOUR RESEARCH FOUNDATION
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Design of electrical equipment and installations for Marquardt Jet Laboratory, the West's largest jet engine testing facility. Responsible for equipment and facilities for testing of fuel systems, hydraulic-pneumatic controls, rotating accessories, and assist in design of test equipment controls and installation of electronic instrumentation.

Job entails evaluation of requirements, job planning and scheduling from concept through installation checkout, cost estimating, liaison, and a nominal amount of board work.

Capable of working with a minimum of supervision and growing with expanding project. Definite potential for advancement to project supervisor. Requires BS-EE degree, plus three to five years experience.

For further information contact: Jim Dale, Professional Personnel, 16555 Saticoy Street, Van Nuys, California.

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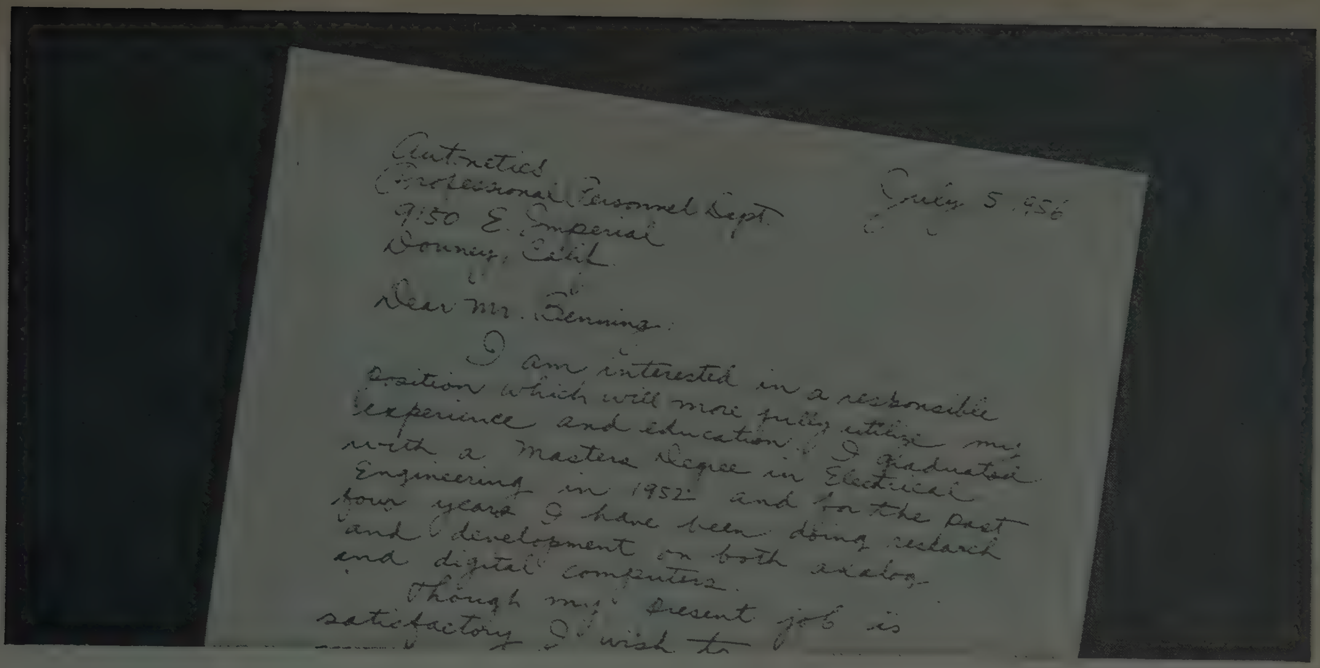

Autonetics
Professional Personnel Dept.
9150 E. Imperial
Downey, Calif.

July 5, 1956

Dear Mr. Benning:

I am interested in a responsible position which will more fully utilize my experience and education. I graduated with a Masters Degree in Electrical Engineering in 1952 and for the past four years I have been doing research and development on both analog and digital computers.

Though my present job is satisfactory I wish to

This letter moved an engineer ahead 5 years

Two years ago a man took 10 minutes to write this letter. Today he enjoys the responsibility and professional standing in the Autonetics Division of North American that might have taken 5 years to achieve elsewhere.

THE 20TH CENTURY'S MOST INTERESTING OPPORTUNITIES FOR THE CREATIVE ENGINEER

Now under way at Autonetics are over 100 projects—military and non-military—involving some of the most arresting and advanced work to challenge the engineering mind today.

WHERE IS YOUR FIELD OF INTEREST?

Inertial Navigation Systems—for aircraft and naval vessels with the organization that successfully flew all-inertial autonavigators more than eight years ago—and whose many-generation family of ever-improved inertial systems for manned and unmanned vehicles have made over 800 successful flights.

Radars—like the lightweight, monopulse type that guides aircraft to targets through fog and darkness and provides all radar functions for both high and low level missions—air-search, automatic tracking, ground-mapping and terrain-avoidance.

Flight Controls—fully automatic and reliable autopilots and landing systems.

Information Processing Equipment—including airborne magnetic tape recorders, transistorized analog or digital computers for both the military and industry, and pace-setting numercial control systems for three-axis position and path control of machine tools for industry.

At finger-tip nearness Autonetics has unique experience, advanced tools and techniques plus precision machine shops turning out work to millionths of an inch tolerances in both developmental and volume quantities.

Opportunities have never been better—at every level of creative engineering from Preliminary research and design to Performance test—**because Autonetics is one of the few companies in the world** designing and quantity-producing systems within the complete spectrum of electronics, electro-mechanics, control engineering and data processing.

Write today and tell us what kind of creative engineering interests you (please include highlights of your education and experience).

Write G. J. Benning, Manager, Employment Services.
9150 E. Imperial Highway, Downey, California

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A DIVISION OF NORTH AMERICAN AVIATION, INC.
NERVE CENTER OF THE NEW INDUSTRIAL ERA

An Invitation To Join ORO...Pioneer In Operations Research

Operations Research is a young science, earning recognition rapidly as a significant aid to decision-making. It employs the services of mathematicians, physicists, economists, engineers, political scientists, psychologists, and others working on teams to synthesize all phases of a problem.

At ORO, a civilian and non-governmental organization, you will become one of a team assigned to vital military problems in the area of tactics, strategy, logistics, weapons systems analysis and communications.

No other Operations Research organization has the broad experience of ORO. Founded in 1948 by Dr. Ellis A. Johnson, pioneer of U. S. Opsearch, ORO's research findings have influenced decision-making on the highest military levels.

ORO's professional atmosphere encourages those with initiative and imagination to broaden their scientific capabilities. For example, staff members are taught to "program" their own material for the Univac computer so that they can use its services at any time they so desire.

ORO starting salaries are competitive with those of industry and other private research organizations. Promotions are based solely on merit. The "fringe" benefits offered are ahead of those given by many companies.

The cultural and historical features which attract visitors to Washington, D. C. are but a short drive from the pleasant Bethesda suburb in which ORO is located. Attractive homes and apartments are within walking distance and readily available in all price ranges. Schools are excellent.

For further information write:
Professional Appointments

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ORO The Johns Hopkins University
6935 ARLINGTON ROAD
BETHESDA 14, MARYLAND

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 174A)

Rack-and-Panel Connector

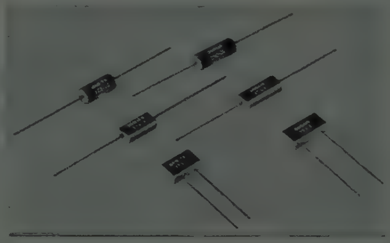
For drawer installations where the connection is blind or inaccessible, these rack-and-panel connectors developed by **The Deutsch Co.,** 7000 Avalon Boulevard, Los Angeles 3, Calif., mate without guide-pins or stop-pins. In the new DM 6502–3719 P/S rack-and-panel plug, six coax contacts and thirteen #20 contacts are provided in the miniature shell. Coax contacts accept RG-196/U cable.

The mated connector is environmentally-sealed, vibration-dampened, unaffected by pressure variations and mates accurately when mounted with commercial tolerances. Deutsch rack-and-panel plugs meet applicable AN "E" requirements for service A voltage rating.

For information write to the firm.

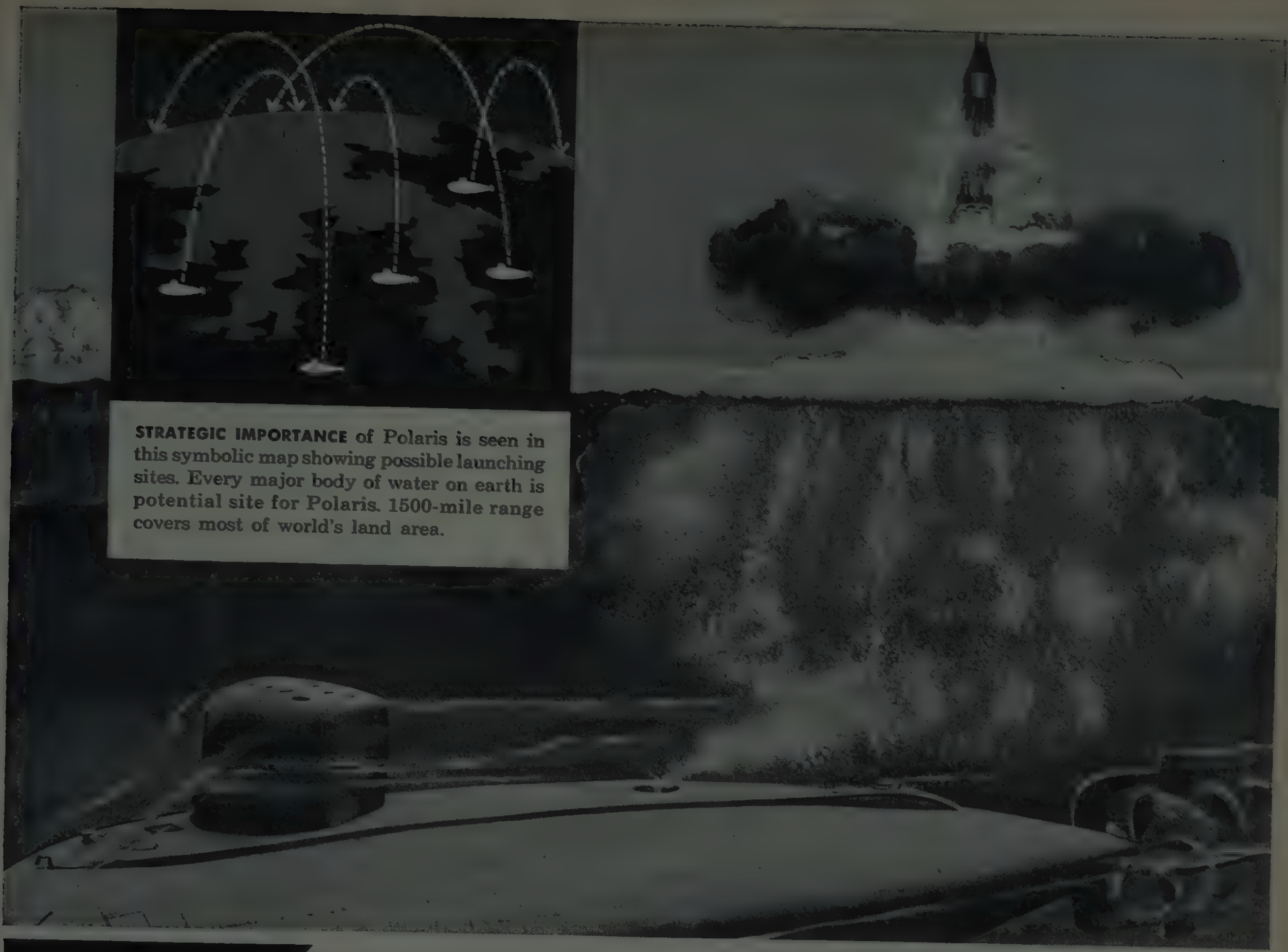
Metal Film Precision Resistors

New Series 77, Metal Film Precision Resistors, produced by **Ohmite Manufacturing Co.,** 3695 Howard St., Skokie, Ill., are now smaller, yet offer higher maximum resistance than the previous models. At the same time, prices of these units have been reduced sharply and are now comparable to, or lower than, quality precision wire-wound units. In the axial lead style, two shapes are now available—a tubular shape and a "flat-side" shape which offers maximum space economy. A radical lead style is also furnished.



Resistance range of the line has been increased and is now 25 ohms to 400 kohms. Standard tolerance is ±1 per cent but tolerances as low as 0.1 per cent can be furnished. A lower standard temperature coefficient of resistance is now provided. 0±25 ppm/°C (0±.0025 per cent/°C) over the exceedingly wide temperature range of

(Continued on page 178A)



STRATEGIC IMPORTANCE of Polaris is seen in this symbolic map showing possible launching sites. Every major body of water on earth is potential site for Polaris. 1500-mile range covers most of world's land area.

CAREER ENGINEERS

Another example of diversified work available to engineers at SPERRY

Sperry offers you the kind of work engineers thrive on—big assignments, interesting, important, diversified. Assignments connected with world-famous projects like the Polaris Missile. Launching a missile at a distant target from a maneuvering atomic sub presents extraordinary navigation problems. Location of the sub must be known precisely. To provide exact navigation data, Sperry is developing for the Navy advanced electronic and gyroscopic systems that will stabilize the sub, continuously establish its precise position and true speed, and feed target data automatically into the missile's guidance system.

That's the kind of assignment you will get, at Sperry. The kind of assignment that puts you side-by-side with some of America's foremost engineers. The kind of assignment that not only offers you a good job *now*, but also exceptional opportunity for advancement. Sperry engineers are career engineers. They grow with the firm—and Sperry has a remarkable record of almost a half century of continuous growth! No wonder most of our top men are engineers who have worked their way up. Our present production and future potential are both at record levels. Check Sperry—now!

If you're interested in an engineering career, CHECK SPERRY

Stimulating Professional Opportunities Exist in Many Fields Including:

INERTIAL NAVIGATION SYSTEMS
DOPPLER NAVIGATION • RADAR RECEIVERS
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SPERRY *GYROSCOPE COMPANY*
Division of Sperry Rand Corp.

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FOR IMMEDIATE DELIVERY FROM STOCK

BAND PASS FILTERS					DISCRIMINATORS				
Catalog No. $Z_0 = 500\Omega$	Catalog No. $Z_0 = 2{,}500\Omega$	3DB Bandwidth per cent of F_0		Center Frequency F_0 (KC)	Per cent Deviation of F_0		Per cent Linearity		Catalog No.
		± 9¾	± 19½		8½	15.	0.5	1.0	
FBP-10	FBP-34	√		.4	√		√		DST-10
FBP-11	FBP-35	√		.56	√		√		DST-11
FBP-12	FBP-36	√		.73	√		√		DST-12
FBP-13	FBP-37	√		.96	√		√		DST-13
FBP-14	FBP-38	√		1.3	√		√		DST-14
FBP-15	FBP-39	√		1.7	√		√		DST-15
FBP-16	FBP-40	√		2.3	√		√		DST-16
FBP-17	FBP-41	√		3.0	√		√		DST-17
FBP-18	FBP-42	√		3.9	√		√		DST-18
FBP-19	FBP-43	√		5.4	√		√		DST-19
FBP-20	FBP-44	√		7.35	√		√		DST-20
FBP-21	FBP-45	√		10.5	√		√		DST-21
FBP-22	FBP-46	√		12.3	√		√		DST-22
FBP-23	FBP-47	√		14.5	√		√		DST-23
FBP-24	FBP-48	√		22.0	√		√		DST-24
FBP-25	FBP-49		√	22.0		√		√	DST-29
FBP-26	FBP-50	√		30.0	√		√		DST-25
FBP-27	FBP-51		√	30.0		√		√	DST-30
FBP-28	FBP-52	√		40.0	√		√		DST-26
FBP-29	FBP-53		√	40.0		√		√	DST-31
FBP-30	FBP-54	√		52.5	√		√		DST-27
FBP-31	FBP-55		√	52.5		√		√	DST-32
FBP-32	FBP-56	√		70.0	√		√		DST-28
FBP-33	FBP-57		√	70.0		√		√	DST-33

DISCRIMINATOR LOW PASS FILTERS

Catalog No.	Center Frequency F_0 (cps)	Catalog No.	Center Frequency F_0 (cps)	Catalog No.	Center Frequency F_0 (cps)	Attenuation
OUTPUT						
LPO-10	6	LPO-19	81	LPO-28	790	< .2 DB to 0.5 F_0 < 7 DB to 1 F_0 > 20 DB to 2 F_0 > 30 DB from 2.5 F_0
LPO-11	8	LPO-20	110	LPO-29	900	
LPO-12	11	LPO-21	160	LPO-30	1,050	
LPO-13	14	LPO-22	185	LPO-31	1,200	
LPO-14	20	LPO-23	220	LPO-32	1,600	
LPO-15	25	LPO-24	330	LPO-33	2,100	
LPO-16	35	LPO-25	450	LPO-34	7,200	
LPO-17	45	LPO-26	600	LPO-35	10,000	
LPO-18	60	LPO-27	660			
Characteristic impedance of all—330Ω						
INPUT						
LPI-10	400	LPI-17	3,000	LPI-23	14,500	.05 DB at 9¾% F_0 30 DB at third 50 DB at fifth Harmonics
LPI-11	560	LPI-18	3,900	LPI-24	22,000	
LPI-12	730	LPI-19	5,400	LPI-25	30,000	
LPI-13	960	LPI-20	7,350	LPI-26	40,000	
LPI-14	1,300	LPI-21	10,500	LPI-27	52,500	
LPI-15	1,700	LPI-22	12,300	LPI-28	70,000	
LPI-16	2,300					
Characteristic impedance of LPI-10 thru 23=30,000Ω of LPI-24 thru 28=5,100Ω						

Write for detailed information on these and other components for military and commercial applications. Send for NEW 48 page TRANSFORMER CATALOG. Also ask for complete LABORATORY TEST INSTRUMENT CATALOG.

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1720 WEIRFIELD ST.
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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 176A)

−55°C to +190°C (25°C reference ambient). Other "T.C.'s" can be provided.

In addition to excellent stability, metal film resistors feature frequency characteristics claimed to be vastly superior to that of wire-wound units. They may be used at full ¼ watt rating in an ambient temperature of 150°C, ⅛ watt at 105°C or derated to "0" at 190°C. Low reactance and noise level make these units particularly suitable for use in high frequency and pulse circuits and also in high gain circuits where the noise level of composition types is excessive.

For additional information (Bulletin 155), write to Ohmite.

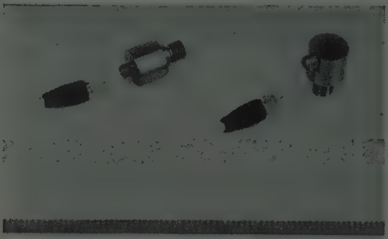
Absorption Analyzer Bulletin

A new 12-page, two-color catalog of test equipment, published by **Kingston Electronic Corp.,** Medfield, Mass. provides detailed descriptions of the three models of Absorption Analyzers and accessory equipment incorporating the much discussed electrostatic pick-up for waveform analysis of electronic circuits having periodic wave forms between 3 mc. and 240 mc.

Also included are other test instruments which the company produces. Complete details, specifications and prices, as well as photographic illustrations of all of the equipment are also included.

High-Sensitivity Accelerometer

Development of two new series of self-generating, high-sensitivity accelerometers, is announced by Abraham I. Dranetz, vice president, **Gulton Industries, Inc.,** 212 Durham Ave., Metuchen, N.J.



Produced by the company's Glennite Instrumentation Division, the new A-380 Series of accelerometers are suited to the measurement of shock and vibration, particularly in the aircraft and missile field.

The new units provide a flat response over temperatures ranging from −70°F to +250°F., with an accuracy of ±5 per cent.

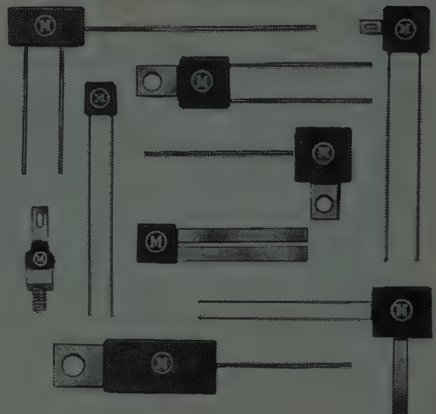
The A-380 Series, self-generating units, have an acceleration range of 0.05 to 500g, and a useful frequency range of 3 to 2,500 cps. Resonant frequency is 10,000 cps, with sensitivity and capacitance (with cables)

(Continued on page 180A)

if you have critical SPACE LIMITATIONS...

MUCON

SUBminiature ceramic capacitors



offer greater

DIMENSIONAL VERSATILITY

Through wider versatility of sizes and lead arrangements . . . plus further diversification with twelve ceramic materials . . . MUCON can fulfill your subminiature capacitor requirements.

MUCON's custom facilities are geared to an

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policy no matter the quantity.

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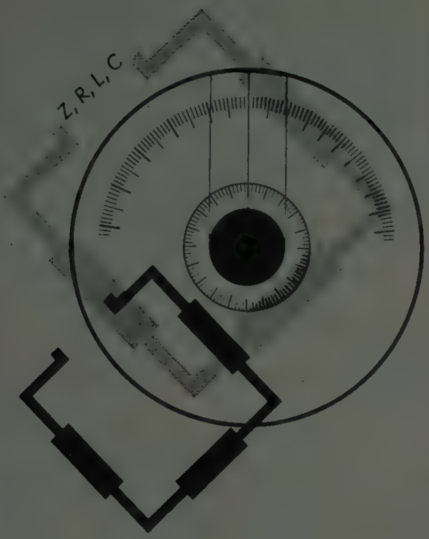
SIEMENS



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The line of products includes:

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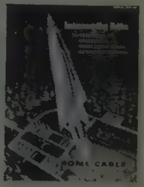
IMPULSE

A DIGEST OF NEW DEVELOPMENTS
IN ELECTRONICS AND AUTOMATION

PUBLISHED BY ROME CABLE CORPORATION, ROME, N. Y.
PIONEERS IN INSTRUMENTATION CABLE ENGINEERING

POLITE POLICEMAN—Tomorrow's vehicle control system might parallel the electronic traffic control system of RCA's David Sarnoff Research Center. Transistorized detector units at the Center count passing cars on roads, measure their speed, and flash a polite warning saying "Slower Please" to drivers exceeding the posted speed limit.

AROUND THE MOON IN 208,000 WATTS—Data-seeking rockets and missiles present a new challenge to telemetry equipment. For example: with present equipment, Army missile experts estimate it would require *208,000* watts to relay a TV panorama of the moon back to earth. Needed: new concepts of conveying data through space.



INSTRUMENTATION CABLE BULLETIN—This 8-page illustrated bulletin discusses cable insulation and jacketing material and lists typical multi-conductor cable constructions available for use with telemetering equipment, data recording equipment, circuit control testing and electronic computers. Every *design engineer* working with electrical cable should have a copy! To obtain your *free* copy write to Rome Cable Corporation, Dept. RCD-400, 421 Ridge Street, Rome, New York.

WEE WIRING—Printed wiring boards, already small, might get even *smaller* soon! How? By eliminating the land area around the holes in the board. This is being done experimentally by some concerns by using plated-through hole techniques. Full-scale production of the new, smaller boards may not be far off.

THE SATELLITE SCOREBOARD—At the date of this writing, the batting averages in the ORBIT LEAGUE looked a little onesided: ARMY (with 3 out of 4 EXPLORERS in orbit) .750*, NAVY (with 1 out of 6 VANGUARDS up) .167.

*(This, incidentally, was better than Stan Musial's average of .339 at the same date.)

CABLEMAN'S CORNER—Not too long ago, a new TV quiz program, entitled "Anybody Can Play," made its debut. No special knowledge was necessary—anyone could answer the questions.

Fine—for TV quiz programs. Dangerous—if applied to cable engineering and manufacture. For 100% reliability in multi-conductor cables—*you must call on a specialist!*

Why? Here are the reasons. If a cable is to be reliable, it must be: 1. Designed by an experienced cable engineer with a working knowledge of instrumentation problems. 2. Constructed of quality material—with the emphasis on solving the need—*and not on the price.* 3. Controlled and thoroughly tested during production. 4. Backed up by a reliable manufacturer who will stand firmly behind every cable produced.

Don't sacrifice reliability in cables for price. Call on a Cable Specialist. Our address is Rome Cable Corporation, 421 Ridge Street, Rome, N. Y.

REDUCE INSERTION LOSS!!
INCREASE USABLE POWER!!

NEW

Kearfott
MIDGET
FERRITE
ISOLATOR

MOD. NO.
SER. NO.
Kearfott COMPANY, INC.
WESTERN DIVISION
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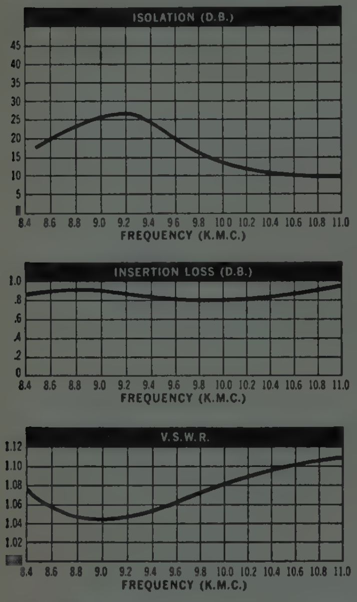
ACTUAL SIZE SHOWN
MODEL W177-IG-2

Typical Performance Curves



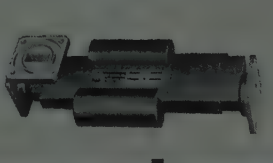
MAXIMUM FREQUENCY STABILITY WHERE SPACE IS LIMITED...

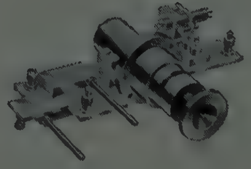
A high power unit of exceptionally small size and weight, this newest Kearfott product is the answer to microwave circuitry applications where space is limited.

IMPORTANT FEATURES:

BROAD FREQUENCY RANGE—from 8.5 to 9.6 KMC
HIGH ISOLATION—Minimum of 15 DB
INSERTION LOSS—Only 1.0 DB Maximum
SMALL SIZE—1.000" deep x 2.100" high x 2.400" high
POWER—Average 200 Watts
TEMPERATURE-AMB—150°C
PRICE—$135.00 each f.o.b., Van Nuys, Calif. Quantity prices on request
DELIVERY—from stock

OTHER STANDARD Ferrite Isolators and Duplexers in a wide range of sizes and band widths are available plus facilities to produce special configurations if desired. Our sales engineers can help you.





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(Continued from page 178A)

of 40mv/g minimum and 1,200 $\mu\mu$f minimum respectively.

The Glennite A-395 Series has an acceleration range of 0.1 to 800g, a useful frequency range of 3 to 9,000 cps and a resonant frequency of 30,000 cps. Capacitance and sensitivity, both cables, are identical to the previous series.

Available in either titanium or aluminum housings, these new instruments utilize a new piezo-electric ceramic for flat response and can be calibrated at higher frequencies on special order.

Power Supply

Model 1515 transistorized power supply manufactured by **Power Designs, Inc.,** 89–25 130th St., Richmond Hill 18, N.Y., is one of a family of portable units protected by Robotec® a transistorized electronic circuit producing simultaneous current and voltage cutoff with an external short circuit. The Robotec® circuit operates in thirty microseconds holding the power supply cut off until manually reset and reducing line input power to a negligible value.

The power supply cannot be turned on if the short circuit persists. Voltage range of the Model 1515 is 1–15 volts dc continuously variable at 0–1.5 amperes; regulation is better than 15 millivolts or 0.05 per cent; ripple is less than 250 microvolts; source impedance is 0.01 ohms and response time less than 50 microseconds. Semiconductor components are utilized throughout including silicon rectifiers and references. Computer quality electrolytic capacitors. Input: 105–125 volts, 55–440 cps. Size: 5¾×8¾×9 inches. Weight: 13 pounds.

Voltage Stabilizer

A new automatic voltage stabilizer, that will maintain a 118 output voltage even though the input may vary from 95 to 130 volts, has just been announced by **Acme Electric Corp.,** Cuba, N.Y.

(Continued on page 182A)

Operate your...

- tape recorder
- P. A. system
- portable TV set
- hand tools

FROM YOUR CAR, *Boat or Plane!*

with ATR

INVERTERS

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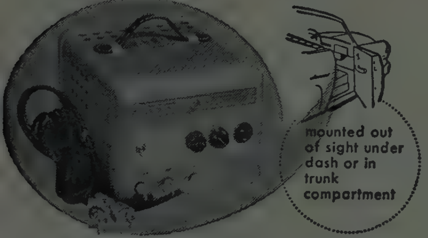

ATR UNIVERSAL INVERTERS

Especially designed to change 6 or 12 volt D.C. to 110 volt A.C. 60 cycles.
for . . .

- EXECUTIVES
- SALESMEN
- OUTDOOR MEN
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MODELS 6U-RHG (6 volts) 125 to 150 watts. Shipping weight 27 lbs. List price..............$89.95
DEALER NET PRICE........$59.97
12U-RHG (12 volts) 150 to 175 watts. Shipping weight 27 lbs. List price.....................$89.95
DEALER NET PRICE........$59.97

Write for literature on other Sizes and Models of ATR INVERTERS, priced as low as $9.95 list.

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✓NEW MODELS ✓NEW DESIGNS ✓NEW LITERATURE
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Quality Products Since 1931
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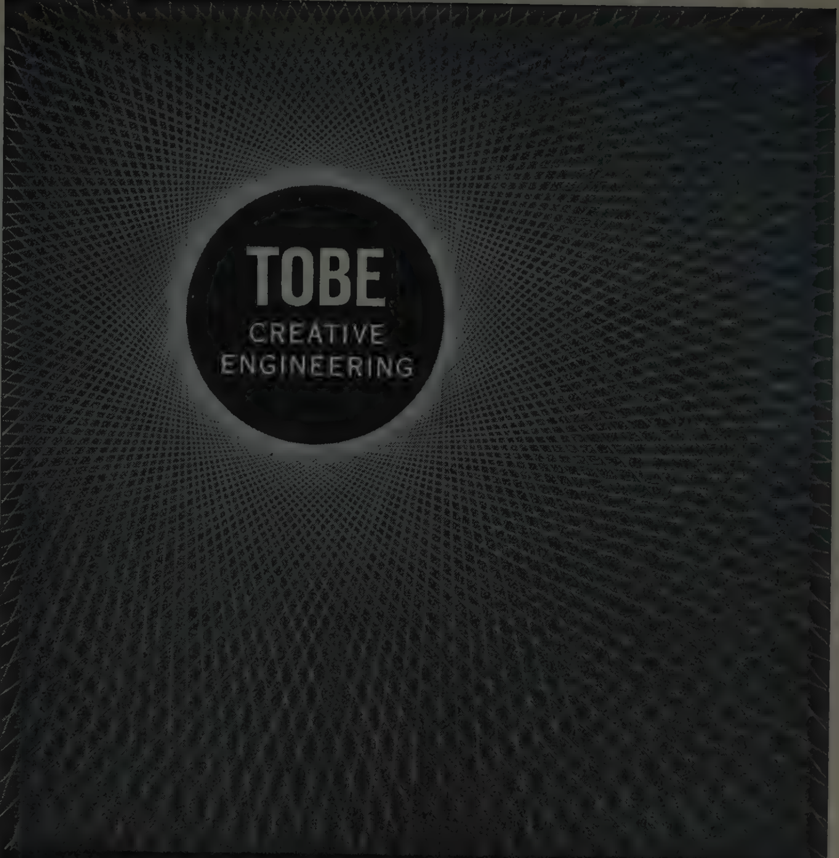
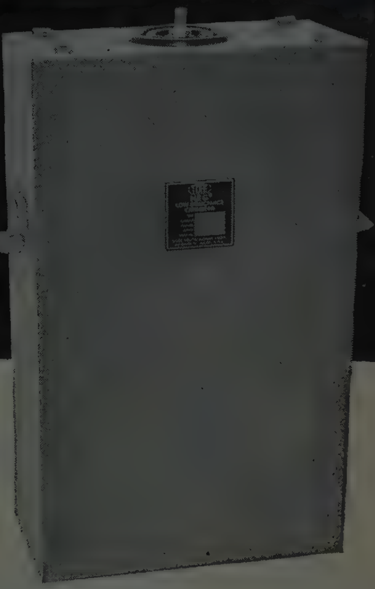


THE NRG-200 SERIES OF LOW-INDUCTANCE THERMONUCLEAR ENERGY-STORAGE CAPACITORS



NRG-200 SERIES SPECIFICATIONS

Type No.	Watt Seconds	Rating		Self Inductance (Microhenries)
		Mfd.	DC Peak	
NRG-201	1000	5.0	20 KV	.04
NRG-202	1500	7.5	20 KV	.045
NRG-203	2000	10.0	20 KV	055
NRG-204	3000	15.0	20 KV	.06

Tobe now announces the availability of a series of reliable, low-cost energy-storage capacitors for thermonuclear equipment and similar applications. The NRG-200 series capacitors have a minimum life expectancy of 1000 operations, and may be operated at ambient temperatures up to 40°C. Maximum permissible reversal voltage is 90%. They can be discharged into a very low-impedance load with complete safety.

For further technical information or engineering aid, write Tobe Deutschmann Corporation, Norwood, Mass.

Specify
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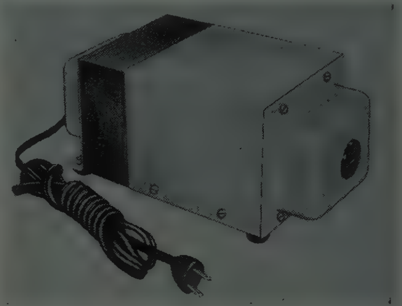
TOBE DEUTSCHMANN • CAPACITOR PIONEERS SINCE 1929

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 180A)

Designed especially for television receivers, amplifiers, hi-fi sets and other electronic equipment, where excessive voltage or low voltage conditions often are the cause of many performance troubles.



According to the manufacturer, this unit, rated at 200 va has capacity to adequately accommodate power requirements of television receivers up to 24 inch screen. The manufacturer claims that the stabilizer's operation is completely noiseless and free from harmonic radiation. While voltage fluctuation over a range from 95 to 130 volts would seldom occur in any one location, yet this unit can accommodate this wide primary range and automatically provide a secondary of 118 volts ±2 per cent within 1/30th second of the occurrence of the primary voltage fluctuation.

The manufacturer points out that a feature of this unit is the built-in relay which automatically disconnects primary circuit when TV set is turned off thus stopping coil magnetism.

Standard unit is furnished with primary cord, and built-in secondary receptacle into which TV cord is plugged.

Steward Names Palmquist

R. N. Palmquist has been appointed Sales Manager for **D. M. Steward Manufacturing Co.,** Chattanooga, Tenn., producers of steatite, ferrites, magnets, insulators and related products.

Palmquist has been associated with D. M. Stewart since 1950 as Sales Engineer for the Chicago territory and more recently metropolitan New York.

Sub-Miniature Air Variable Capacitor

The Type "U" sub-miniature air variable capacitor by **E. F. Johnson Co.,** Waseca, Minn. requires less than two-tenths (0.2) square inch for chassis or panel mounting. The rotor and stator are machined from one piece of solid brass providing outstanding mechanical stability and uniformity. This new capacitor is designed to provide long, trouble free

(Continued on page 184A)

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BASE METAL WIRES . . . Very small diameter—for filaments, thermocouples, resistance units.

PRECIOUS METAL WIRES . . . Produced in Platinum, Gold, alloys and pure metals—small diameter . . . Platinum alloy resistance wires.

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10dbm and 30dbm

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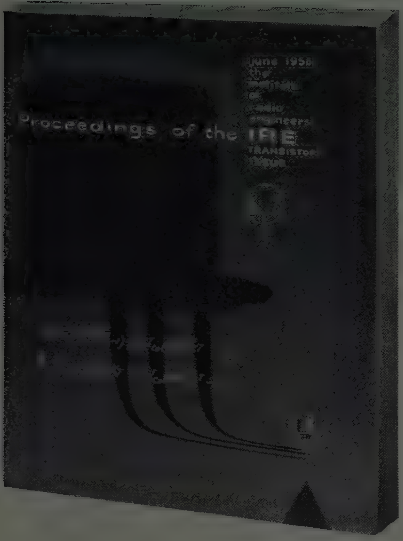
THE DECADE OF THE TRANSISTOR

IRE commemorates the tenth anniversary of a major breakthrough in solid state electronics by devoting the entire June issue of PROCEEDINGS OF THE IRE to an up-to-date summary of progress and advances in transistors. So small that many can be held in the palm of one hand, these tiny components have ended our 50 year dependence on vacuum tubes. Without transistors, our intricate guidance and communication systems for missiles would be incredibly big and heavy. With them, whole new technologies are being developed, not only for defense but for industry and commerce as well.



June Issue of Proceedings of the IRE is the New Standard Reference Work on Transistors

Only once before has PROCEEDINGS devoted an entire issue to transistors. That was in November, 1952. Despite a substantial overprinting, every copy was sold within 3 months. This classic issue, coming at a time when there were no books and few papers on the subject, is still considered one of the basic references on the subject...a suitable companion to the definitive Solid-State Electronic issue of December, 1955 and the Ferrites issue of October, 1956.

Now, to mark the tenth anniversary of the transistor, PROCEEDINGS presents the latest advances in theory and application in the June, 1958 issue. Here you will find introductory articles by its inventors—Shockley, Bardeen and Brattain—specially invited papers reviewing progress in all facets of the subject, contributed papers reporting the latest and more important advances in the field. Be sure to order your copy, today!

Partial Contents:

"The Technological Impact of Transistors," by J. A. Morton & W. J. Pietenpol, Bell Labs.
"The Status of Transistor Research in Compound Semiconductors," by D. A. Jenny, RCA.
"Survey of Other Semiconductor Devices," by S. J. Angello, Westinghouse.
"Electrons, Holes and Traps," by W. Shockley, Shockley Semiconductor Lab.
"Recombination in Semiconductors," by G. Bemski, Bell Labs.
"Noise in Junction Transistors," by A. van der Ziel, University of Minnesota.
"Formation of Junction Structures by Solid State Diffusion," by F. M. Smits, Bell Labs.
"Germanium and Silicon Rectifiers," by H. Henkels, Westinghouse.
"The Potential of Semiconductor Diodes in High-Frequency Communications," by A. Uhlir, Bell Labs.
"Advances in the Understandings of the P-N Junction Triode," by R. L. Pritchard, Texas Instruments.
"Power Transistors," by M. A. Clark, Pacific Semiconductors.
"Application of Transistors in Computers," by R. A. Henle & J. L. Walsh, IBM.
"Application of Transistors in Communication Equipment," by D. D. Holmes, RCA.
"Characteristics Data on Silicon and Germanium," by E. Conwell, Sylvania.

The Institute of Radio Engineers
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○ Enclosed is $3.00

○ Enclosed is company purchase order for the June 1958 issue on Transistors.

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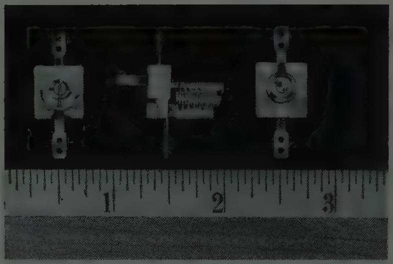
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 182A)

life and absolute freedom from moisture entrapment found in trimmer capacitors of the enclosed or solid dielectric type.



The precisely plane and paralleled surfaces of plates, extra heavy rotor and stator mounting techniques, high "Q", high torque to mass ratio and low temperature coefficient are all important advantages of this new product. All metal parts are silver plated, ceramic is steatite, Grade L-4 or better. Exceptionally uniform delta C and voltage characteristics, breakdown ratings to 1,300 volts dc. Simple, economical, foolproof, requires no special tool for installation or adjustment. Specials are available in production quantities to meet varied application requirements. Request data sheet #756.

C-Band Circulator

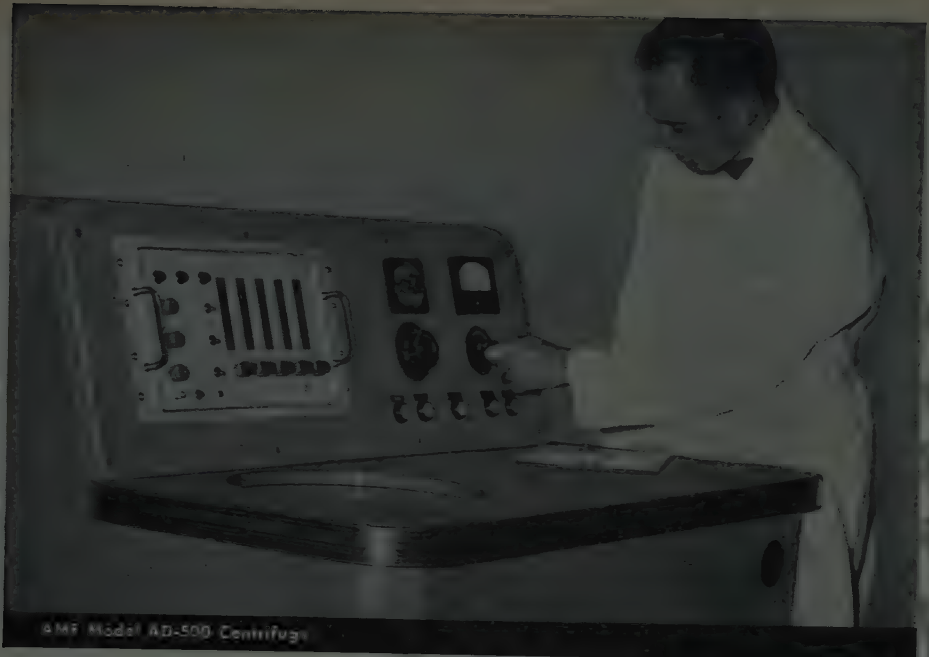
A new C-Band Ferrite Differential Phase Shift Circulator with exceptional isolation to insertion loss characteristics has recently been announced by **Kearfott Company, Inc., Microwave Div.,** 14844 Oxnard St., Van Nuys, Calif., manufacturers of precision microwave components and test equipment.

Designated as Model W269-2A-1, the new unit operates over the common barrier (fixed) and mobile bands between 5.975 kmc and 6.425 kmc. Isolation is better than 20 db between any input terminals and arbitrary output terminals, while insertion loss is less than 0.7 db over the entire range. VSWR is less than 1.25 at any input terminal over the band.

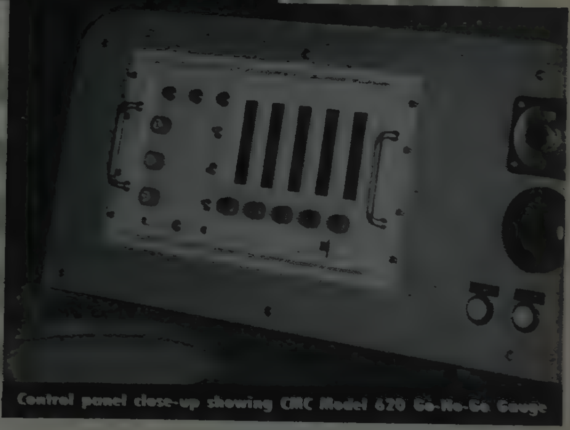
Other features include a peak power handling capability of 1.0 kw. Average powers may be handled up to 20 W making it ideal for "data link" applications. Operating temperature range is −30°C to +125°C. Size is indicated at $11\frac{7}{8}\times4\frac{7}{8}\times3\frac{13}{16}$ inches with weight at $5\frac{1}{2}$ pounds.

Further information on the Model W269-2A-1 may be obtained on request from the manufacturer.

(Continued on page 186A)



AMF Model AD-500 Centrifuge



Control panel close-up showing CMC Model 620 Go-No-Go Gauge

How AMF uses CMC electronic counting equipment

For Motor Speed Control

American Machine & Foundry's Model AD-500 is a high speed centrifuge for environmental testing of electronic components. Capable of exerting acceleration forces up to 50,000 G's at 22,000 RPM, the completely automatic Model AD-500 requires a precise speed control system. The system must provide maximum user flexibility and simplicity of operation. AMF chose the CMC Model 620 Go-No-Go Gauge to give their Model AD-500 precise speed control within any pre-selected limits.

Basically, the CMC 620 is a dual preset counter with a built-in time base, which provides output information in the form of relay closures for control purposes. Before the Model AD-500 is started, upper and lower RPM limits are set on the control knobs of the dual preset decade units. The test is then begun. As the centrifuge rotates, a tachometer generator provides the input information to the Model 620 which reads directly in RPM. If the motor speed falls within the pre-selected limits, the green "IN LIMITS" lamp lights. Above or below limits, the red "HIGH" or "LOW" lamp lights and the associated relay closure takes place, de-energizing or re-energizing the motor to hold the centrifuge within pre-selected limits.

For complete specifications, description, price and applications information on the CMC Model 620, please address Dept. 439.

OTHER APPLICATIONS...

Include—material flow control, production line testing of electronic instruments and components, pressure or liquid flow regulating-indicating systems, etc.

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7

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F-28/APN-19 FILTER CAVITY

Jan. spec: Tuneable 2700-2900mc, 1.5db max. loss at ctr freq over band. Details: Insertion loss variable. Single tuned filter for freq channelling in radar beacon. Invar center tuning conductor ¾ wavelength. New $37.50 each.

RADIOSONDE TRACKING RADAR. AN/SMD-1 (ANGMD-1) Mfg. General Electric 1700 MC System consists of console dynamo amplifiers, synchro amplifiers, antenna system, transmitter, receiver. Price $6500.

10 CM. WEATHER RADAR SYSTEM

US Navy Raytheon 275 KW peak output S band. Rotating yoke Plan position Indicator. Magnetron supplied for any S band frequency specified, incl. Weather Band. 4, 20 and 80 mile range. 360 degree azimuth scan. Sensitive revr using 2K28 and 1N21B. Supplied brand new complete with instruction books and installation drawings. Can be supplied to operate from 32VDC or 115 volts. Price $975. Ideal for weather work. Has picked up clouds at 50 miles. Weight 488 lbs.

RT39/APG-5 & 15 10CM RADAR. Complete S band RF package. Lighthouse 2C40 xmtr. 2C43 revr, TR, 829B pulser, miniature 6AK5 IF strip. Press. 12" dia., 24" lg. New with tubes $275. Ref: MIT Rad. Lab. Series Vol. I, pg. 207.

3CM. KLYSTRON MOUNT

2K25-723A/B mount with cplg. to waveguide run and afc. Shielded incl. tuning rod. Matching tuneable output slugs. Dual crystal mount. Pwr cable w/min. plug. Brand new. $28.50.

AN/APN-60

10 CM. RADAR BEACON FOR GUIDED MISSILES. 14" pressurized housing. 2C46 lighthouse osc. Trans-revr. unit $275.00.

⅞" RIGID COAX. 50 ohm, standard fittings, 10cm stub supported. 12 ft. lengths. Silver plated. New $34.50 each. 12 ft. length. Right angle bends $6 ea.

2C37 SYLVANIA ROCKET TUBE $17.50. Complete mixer assy cavity with FM sweeping motor. [illegible] Sperry. Brand new $65.00.

TOPWALL HYBRID JUNCTION. [illegible] 1x.5 wg size. Broad banded better than 16%. Aluminum casting. $15.00 new. Crossover output, 1x.5 wg size. $5.00 new.

BROAD BAND BAL MIXER using short slot hybrid. Pound type broad band dual balanced crystal holder. 1x.5 wg size. $25.00 new.

FLEXIBLE WAVEGUIDE. 1x.5 X band 9" Technicraft. New $10.00. 1x.5 X band 24" Airtron. New $21.50. 1¼ x ⅝" X band 12" Western Elec. New $19.50.

COAX MIXER ASSEMBLY 1N21 type crystal detector RF to IF, "N" fittings, matching slug, duplex couplings, mfg. G.E. New, $18.50.

FOR SALE COMPLETE SCR 584 RADAR

Our 584 is in like new condition, ready to go, and in stock for immediate delivery. Ideal for research and development, airway control, limited GCA, missile tracking, balloon tracking, weather forecasting, antiaircraft defense, tactical air support. Write us. Fully Desc. MIT Rad. Lab. Series, Vol. I, pps. 207-210, 228, 284-286.

AN/MPN-1A GCA SET

Ground control approach equipped trailer with 3 cm precision and 10 cm search radars plus full complement precision and search indicators. All in original trailer. Call—write for info. and price. Fully Desc. MIT Rad. Lab. Series, Vol. II, pps. 237-251.

3KW 400 CYCLE SOURCE

Complete generator set 115vdc 4HP motor (easily swapped for standard GE or other 115v 60 cycle AC motor) speed regulated. Generator output 115 volts 400 cycle single phase 17.4 amps continuous duty. Output electronically regulated. Built to rigid US Navy spec. In excellent used condition. A new special price $285.00. With 115VAC 60 cycle single phase motor $385 incl. compl. regulator.

PRESSURIZED WINDOW 1 x ½" guide Varian [illegible]

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SMX-32 Amplifier-Multiplier 9.0-10.5 KMC. Amp. freq. multiplier: output power 1.5 to 2 watts at 9000 to 10,500 mc; drive freq. 4500 to 5250 mc. New in original sealed cartons. Guaranteed 90 days. Regular price $925 ea. Our price $425 ea.

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2 Watt X Band Power Source: mfg. Sperry. Delivers 2 full watts RF at X band. 6 ft. rack 115v ac input. Brand new. Also delivers 1 watt at C band 4000mc and 750mc rf. Price complete with all tubes, etc. $2500.

COMPLETE RADAR PLUMBING FRONT END. c/o 2K25 local osc. mount, 2K25 beacon mount, type N adapter, crystal mount with tuning slug, variable attenuator, beacon xtal mt. beacon N adapter, also matching duplexer assy. Latest type Navy Radar. Ideal for radar front end or as a complete laboratory bench set up. Price incl. duplexer $[illegible]. Less duplexer $[illegible]. Brand new electrical and mech. tested.

CRYSTAL MOUNTS

X band. Broad banded BNC [illegible] output [illegible] Flange Input. VSWR better than 1.0 Mfg. Airtron. New. $[illegible] ([illegible])

S band. Type N ⅞ coax. [illegible] New $[illegible] each.

TAPER [illegible]

ANTENNA PEDESTAL SCR 584—MP 61B

Full azimuth and elevation sweeps. 360 degree azimuth. 210 degree elevation. For full tracking response. Includes pedestal drives, selsyns, etc. Excellent used condition. (Illus.) This is the first time these pedestals have been available for purchase. Limited quantity in stock for immediate shipment.

Complete description in McGraw-Hill Radiation Laboratory Series, Volume I, page 284 and page 289, and Volume 26, page 233.

AN/APS-10

Complete RF head including transmitter, receiver, modulator. Uses 2J42 magnetron. Fully described in MIT Rad. Lab. Series Vol. I, pps. 616-625 and Vol. II, pps. 171-185. $375.00.

KLYSTRON MOUNTS

3CM. Precision Tube Mount. Waveline model 688. X band shielded klystron mount PRD signal generator type. Complete with variable glass vane attenuator. Brand new. $205. list. Price $[illegible]

S. band. Type N output. Tuneable over entire band. For [illegible] type tube [illegible] & tube clamp. Mfg. GE. New. $15.00.

K band. [illegible] output cplg. w/90 deg. H bend. New. $[illegible]

10 CM. DUAL CHANNEL BEACON RECEIVER

Low level converter rf to dc to control amplifiers. In pressurized housing apx. 6 in. dia., 10 in. lg. Uses 1N27 crystals. $52.50 each. F-28/APN-19 filters for above $37.50 each.

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X band. 3 types. a) uni-directional CG-176/AP. b) bi-directional. c) cross guide mfg. Airtron. All apx. 20db. All RG52 guide w/standard flanges. New $[illegible] each.

X band. RG52 U bi-directional. Airtron calibrated 20db. New $[illegible]

K band. 1.25 cm. 20db CU-[illegible] Mfg. ARC. Std. fittings. Coin silver. New $45.00.

SPERRY MICROLINE double slug tuner for ⅞" coax Model [illegible] $[illegible]

TS[illegible]/CPM4 DUMMY T-R BOX 10 CM. [illegible] [illegible] $37.50.

ANTENNA GYRO STABILIZER. Bendix Gyro Servo Unit. Combined horizon gyro, Autosyn & tilt correction motor. Maintains tilt stabilization of radar antenna, etc. Pioneer 15[illegible]-1-B APS-15). New $[illegible] Ref: MIT Rad. Lab. Series, Vol. I, pps. [illegible]

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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 154A)

Del Appoints Kaufman

Del Electronics Corp., 521 Homestead Ave., Mount Vernon, N.Y., manufacturers of high voltage equipment, announce the appointment of Dr. Raymond Kaufman to the position of Vice President and Director of Research.

Kaufman was formerly with the Farrand Optical Co., Inc., in the position of Senior Physicist and Project Engineer. Prior to that, he was an instructor in the Physics Department of the College of the City of New York. He received his Bachelor's degree at City College and his Masters and Ph.D. degrees at New York University. In his new capacity, he will be responsible for the direction of the various research projects at Del.

DC Source

A simple to operate accurate source of pure dc from 0 to 67.5 volts has been announced by **Kingston Electronic Corp.**, Medfield, Mass. The unit, known as the Model BB-1 variable dc source, is battery-driven, and will produce dependable negative bias voltages for AGC trouble-shooting, alignment and experimental or laboratory work. A two-scale meter insures accurate setting, and allows for correcting for various load conditions. Battery life, when discharged four hours per day to an end point of 45 volts, is approximately 80 hrs. and is greatly extended when use is intermittent. Battery is not supplied, but is a standard type. Price is $14.95.

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MODEL NO.	231T-1	231T-2	231T-3	231T-4
Frequency band, kmc	1-2	2-4	4-8	8-12
Rep or sweep rate, pps*	40-4,000	40-4,000	10-10,000	10-10,000
F-M deviation, mc	2.5	2.5	5.0	5.0
Pulse width, usec	0.5-10	0.5-10	0.2-10	0.2-10

*For pulsed, square-wave, f-m; internal or external modulation

Only a few indicative specifications are shown. For fuller details ask your Levinthal representative about data sheets, or communicate with the main office shown below.

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Among the transmitters, modulators, power supplies, and accessories for radar, communications, and tube development which have already been produced, there may be units suitable for the solution of your problems. Let us send you a descriptive folder on these or discuss with you the design, development, and production of specialized equipment for your particular needs.

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Advertising Index

IRE News and Radio Notes 14A
IRE People 42A
Industrial Engineering Notes 106A
Meetings with Exhibits 8A
Membership 62A
News—New Products 40A
Positions Open 134A
Positions Wanted by Armed Forces Veterans 138A
Professional Group Meetings 84A
Section Meetings 94A
Table of Contents 1A-2A
Whom and What to See at the IRE National Symposium on Telemetering ...98A

DISPLAY ADVERTISERS

A C Electronics Div., General Motors Corp. ..143A
AMP Incorporated 37A
Abbott's Employment Specialists 164A
Accredited Personnel Service 173A
Adage, Inc. 46A
Airborne Instruments Lab. 4A
Allen-Bradley Co. 35A
Allied Radio 76A
American Television & Radio Co. 181A
American Time Products, Inc. 113A
Ampex Corporation 101A
Amphenol Electronics Corp. 48A
Argonne National Lab. 157A
Armour Research Foundation, Illinois Institute of Technology 164A, 174A
Arnold Engineering Co. 103A
Audio Engineering Society 60A
Autonetics Div., North American Aviation, Inc. 175A
Avco Mfg. Corp., Advanced Research & Development Div. 169A
Avco Mfg. Corp., Crosley Div. 138A
Avion Div., ACF Industries, Inc. 170A

Ballantine Laboratories, Inc. 66A
Beede Electrical Instrument Co., Inc. 83A
Bell Aircraft Corp. 142A
Bell Telephone Labs. 6A
Belleville-Hexem Corp. 84A
Bendix Aviation Corp., Kansas City Div. 58A
Bendix-Pacific Div., Bendix Aviation Corp. ...142A
Bendix Aviation Corp., Red Bank Div. 99A
Berkeley Div., Beckman Instruments, Inc. ..70A-71A
Bickel, Richard L. 188A
Boeing Airplane Co. 137A
Bomac Laboratories, Inc. 17A
Borg Equipment Div., George W. Borg Corp. 80A-81A
Bussmann Mfg Div., McGraw Edison Co. 129A

CBS—Hytron Div. 31A
Cannon Electric Co. 39A
Capitol Radio Engineering Institute 64A
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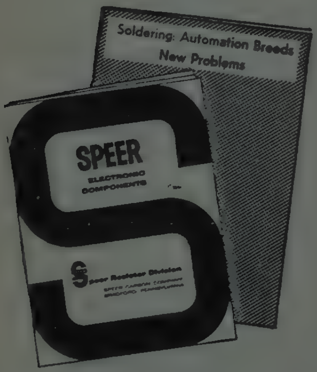

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Advertising Index

Clearprint Paper Co. 25A
Cohn Corp., Sigmund 182A
Collins Radio Co. 165A
Communication Products Co. 130A
Computer-Measurements Corp. 185A
Continental Consultants Incorporated 154A
Cornell Aeronautical Lab., Inc. 145A
Cornell-Dubilier Electric Corp. ....Cover 3
Corning Glass Works 79A
Cosmic Condenser Co. 84A

Dale Products, Inc. 47A
Daven Company 49A
Del Electronics Corp. 60A
DeMornay-Bonardi 133A
Deutschmann Corp., Tobe 181A
Dewey & Co., Inc., G. C. 86A
Donner Scientific Co. 112A
Driver Co., Wilbur B. 10A

E S C Corporation 43A
Ehrenfried, A. D. 188A
Eitel-McCullough, Inc. 67A, 91A
Electrical Industries 21A
Electro-Measurements, Inc. 131A
Electro Motive Mfg. Co., Inc. 57A
Electronic Research Associates, Inc. 8A
Elgin Metalformers Corp. 68A
Ellis, David 188A
Empire Devices Products Corp. 38A
Engineering Associates, Inc. 93A
Erie Resistor Corp. 72A

F-R Machine Works, Inc. 87A
Fairchild Semiconductor Corp. 27A
Farnsworth Electronics Co. 145A
Ferroxcube Corp. of America 74A
Freed Transformer Co., Inc. 178A
Fusite Corporation 63A

General Ceramics Corp. 11A
General Electric Co., Apparatus Sales Dept. 107A
General Electric Co., Missile & Ordnance Systems Dept. 166A
General Electric Co., Power Tube Dept. 120A-121A
General Electric Co., Receiving Tube Div. 73A
General Electric Co., Technical Personnel Dept. 154A
General Mills, Inc., Mechanical Div. 144A
General Radio Co. ....Cover 4
Goodyear Aircraft Corp. 166A
Gould, Norman S. 188A
Grace Electronic Chemicals, Inc. 69A
Gudebrod Brothers Silk Co., Inc. 126A
Guilford Personnel Service 154A

Hallmark, Clyde E. 188A
Hardwick, Hindle, Inc. 130A
Heath Company 88A
Hewlett-Packard Company 12A-13A, 33A
Huggins Laboratories 111A, 191A
Hughes Aircraft Co. 52A-53A, 152A-153A

Induction Motors of Calif. 64A
Institute of Radio Engineers 44A-45A, 104A, 128A, 133A, 154A, 183A, 189A
International Business Machines Corp. 135A
International Eastern 133A
International Electronic Research Corp. 116A
International Tel. & Tel. Corp. 145A

J-V-M Microwave Co. 131A

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Advertising Index

Jeffers Electronics Div., Speer Carbon Co. ...190A
Johns Hopkins University, Applied Physics Lab. ...155A
Johns Hopkins University, Operations Research Office ...176A
Jones Div., Howard B., Cinch Mfg. Corp. ...110A

Kahn, Leonard R. ...188A
Kay Electric Co. ...9A
Kearfott Co., Inc. ...108A
Kearfott Co., Inc., Microwave Div. ...180A
Kennedy & Co., D. S. ...85A
Kepco Laboratories, Inc. ...74A
Knights Company, James ...90A
Knopow, Howard S. ...188A
Kollsman Instrument Corp. ...158A

Lambda Electronics Corp. ...109A
Levinthal Electronic Products, Inc. ...187A
Link Aviation, Inc. ...167A
Litton Industries, Maryland Div. ...134A
Lockheed Aircraft Corp. ...160A-161A

Magnetics, Inc. ...36A
Marquardt Aircraft Co. ...174A
Martin Company ...151A
Massachusetts Institute of Technology, Instrumentation Lab. ...172A
Massachusetts Institute of Technology, Lincoln Lab. ...158A
Matthews & Co., Inc., Jas. H. ...122A
Mayberry, Len ...188A
McGraw-Hill Book Co., Inc. ...132A
Measurements, A McGraw-Edison Div. ...192A
Melpar, Inc. ...162A
Menlo Park Engineering ...182A
Microwave Associates, Inc. ...151A, 184A
Millen Mfg. Co., Inc., James ...64A
Moskowitz, S. & D. D. Grieg ...188A
Motorola, Inc., Semiconductor Products Div. ..89A
Motorola, Inc., Western Military Electronics Centre ...144A
Mucon Corporation ...178A

Narda Microwave Corp. ...105A
Nexon, V. J., S. K. Wolf, and M. Westheimer ...188A
Ney Company, J. M. ...100A
Norden Labs., Norden Div., United Aircraft Corp. ...156A
North American Aviation, Inc. ...150A, 164A, 175A
Northern Radio Co., Inc. ...60A

Offner Electronics, Inc. ...29A
Ordnance Research Lab., Pennsylvania State Univ. ...142A
Oster Mfg. Co., John ...119A
Ostlund, Evert M. ...188A

Panoramic Radio Products, Inc. ...100A
Parke, Nathan Grier ...188A
Permanent Employment Agency ...166A
Philco Corp., Lansdale Tube Co. Div. ...62A
Polytechnic Research & Dev. Co. ...127A
Precision Apparatus Co., Inc. ...102A

Radio Corp. of America, Astro-Electronic Products Div. ...140A
Radio Corp. of America, Electron Tube Div. ...65A, 96A
Radio Corp. of America, Missile & Surface Radar Dept. ...173A

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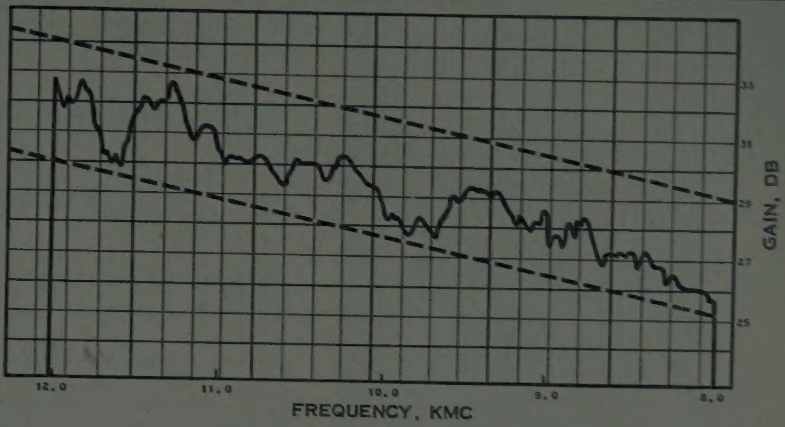

RECORDED PLOT OF SMALL SIGNAL GAIN VS FREQUENCY OF A MODIFIED HUGGINS HA–20 PM FOCUSED TWT AMPLIFIER

The production department at Huggins Laboratories has become very adept at providing traveling wave tubes having specific performance characteristics. These characteristics generally have stressed achievement of a prescribed small signal gain as a function of frequency over definite frequency bands, depending on customer requirements.

As an example, tubes can be provided in which small signal gain varies at some prescribed rate as a function of frequency. The use of a TWT whose gain increases as frequency increases makes it possible to compensate for losses of other microwave system components, which generally increase with frequency, also. The over-all result is a system which, between two given points, has a response which is very nearly independent of frequency. Traveling wave tubes having such properties have been supplied over several specific frequency ranges within the 2.0 to 12.4 KMC bands.

The curve above gives an example of the extent to which the small signal gain response of a TWT amplifier may be controlled. Here, the modification of a standard X-band PM-focused amplifier resulted in an average gain which increased by 1.5 db per 1000 MC increase in frequency over the 8.0 to 12.0 KMC band. Response of this type is possible with no adjustment necessary by the user external to the tube — the curve is presented with all potentials and currents fixed. Other types of gain responses are also possible, such as TWT amplifiers whose gain varies at some fixed rate over certain particular frequency bands.

The curve is a plot made with a pen recorder used in conjunction with a constant power system. This system makes use of a gridded low-level TWT and the use of feedback to control its output such that it is very nearly constant as a function of frequency and drive (over certain input level ranges). Such a system is described in Huggins Engineering Note, Number 8, *"The use of the TWT in constant power systems."*

A copy of this is available upon your request, and is bound in our two-volume catalog set which is also available should you not already be on our mailing list. Submit inquiry on company letterhead.

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Advertising Index

Radio Engineering Products Ltd. 86A
Radio Materials Co. 123A
Radio Research Instrument Co. 186A
Ramo-Wooldridge Corp. 97A
Raytheon Mfg. Co., Industrial Tube Div. 7A
Raytheon Mfg. Co., Magnetic Components Dept. 82A
Raytheon Mfg. Co., Microwave & Power Tube Div. 41A
Raytheon Mfg. Co., Personnel Recruitment ... 165A
Reeves-Hoffman Div., Dynamics Corp. of America 106A
Republic Aviation Corp. 139A
Rheem Electronics Div., Rheem Mfg. Co. 104A
Rider, Publisher, Inc., John F. 42A
Rixon Electronics, Inc. 94A
Rome Cable Corporation 179A
Rosenberg, Paul 188A
Ryan Aeronautical Co. 149A

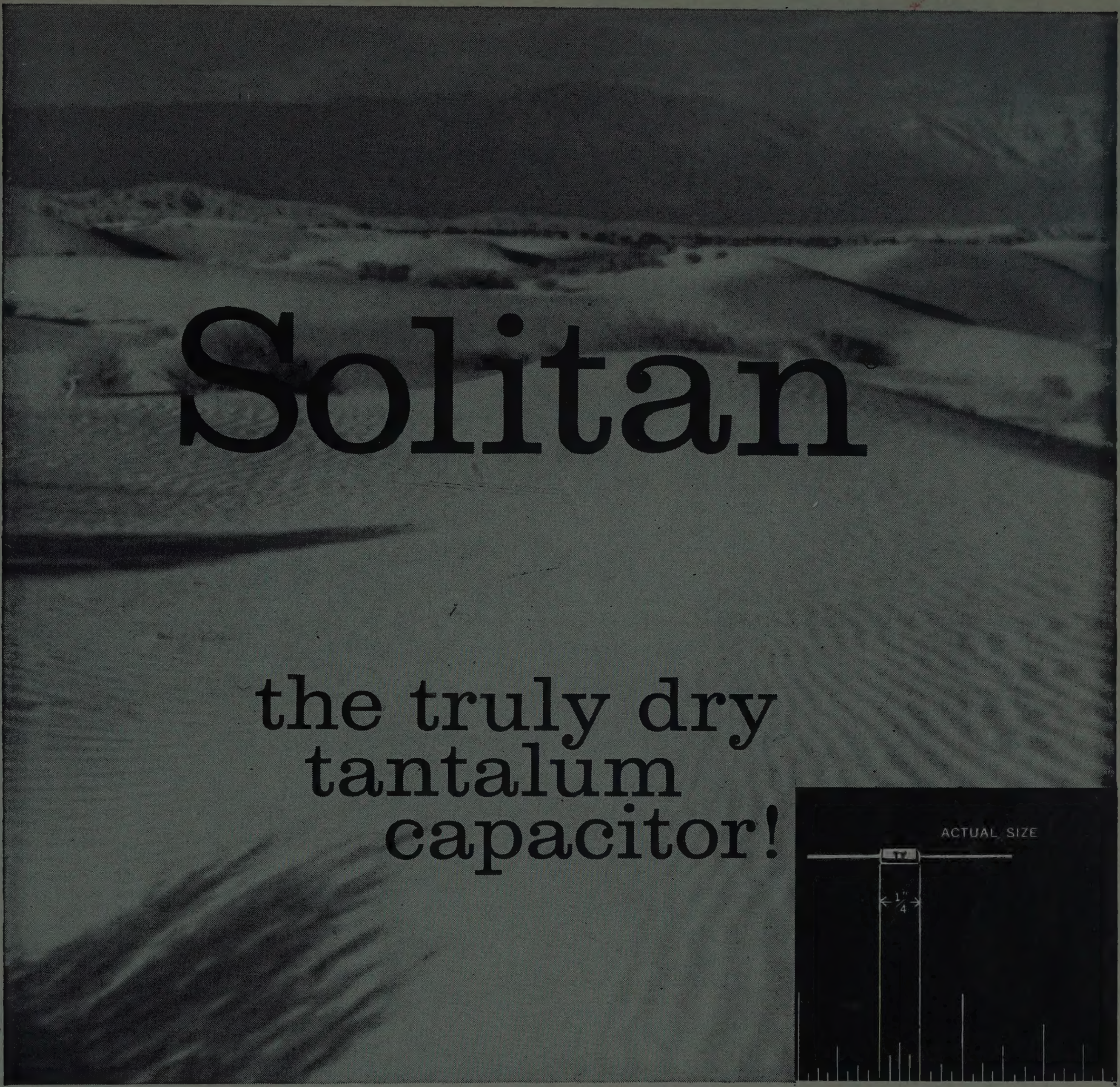
Sanborn Company 51A
Sandia Corporation 141A
Scientific-Atlanta, Inc. 110A
Sherry Personnel Service 172A
Siemens New York, Inc. 179A
Singer Mfg. Co. 115A
Sola Electric Co. 92A
Speer Resistor Div., Speer Carbon Co. 190A
Sperry Electronic Tube Div., Sperry Rand Corp. 150A
Sperry Gyroscope Co., Div., Sperry Rand Corp. 177A
Sperry Microwave Electronics Co., Div. Sperry Rand Corp. 136A
Spittal, William R. 188A
Sprague Electric Co. 3A, 5A
Stanford Research Institute 158A
Statham Instruments, Inc. 125A
Steafix 114A
Stoddart Aircraft Radio Co., Inc. 84A
Stromberg-Carlson Company 56A, 163A
Swift Textile Metalizing and Laminating Corp. 122A
Sylvania Electric Products Inc., Semiconductor Div. 23A
Sylvania Electric Products Inc., Tube Div. .... facing 36A-37A
Sylvania Electric Porducts Inc., Personnel Recruitment 146A-148A
Syntronic Instruments, Inc. 114A
System Development Corp. 171A

Tektronix, Inc. 75A
Texas Instruments Incorporated 19A, 61A, 95A
Thompson-Ramo-Wooldridge Products Co. ... 172A
Times Facsimile Corporation 104A
Trans-Sonics, Inc. 98A
Triad Transformer Corp. 93A
Tung-Sol Electric, Inc. 59A, 117A

U. S. Stoneware Co., Alite Div. 55A
United Transformer Corp. .... Cover 2

Varian Associates 118A
Vitramon, Inc. 90A
Vitro Laboratories, Silver Spring Lab. 159A

Wallace, Don C. 188A
Washington Aluminum Co., Inc. 74A
Westinghouse Electric Corp. 168A
Wheeler, Harold A. 188A
Wiley & Sons, Inc., John 50A, 62A, 106A



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